10 AIRCRAFT THAT CHANGED THE WORLD

AIR&SPACE

Smithsonian

Million Mile Mission

CATCH UP WITH AN ASTEROID

The Airplane That Beat The Bomb

Brave New Airspace: Meet The Robo-Planes

P. 16

JULY 2008

LEECHES. ALIENS. CARBON SEQUESTRATION.

(Perfect topics for your next barbeque...)

This summer, explore the how and why of science and technology with Neil deGrasse Tyson and the team from NOVA scienceNOW.

NOVA scienceNOW™

pbs.org/novasciencenow

Funding provided by: Pfizer nsf HHMI ALFRED P. SLOAN FOUNDATION

WEDNESDAYS STARTING
JUNE 25 9PM ET PT

Be more PBS

Just Arrived From "Down Under"

The New 2008 Silver Koala!

Australia's Silver Koalas are back! They traveled halfway across the globe to reach America—and now you have the opportunity to make the new 2008 Silver Koala coins from "Down Under" part of your collection!

FIRST-EVER, Exclusive U.S. Release

Thanks to an exclusive agreement with Australia's world-famous Perth Mint, New York Mint has secured the rights to the first 8,000 coins struck of this brand new Silver Koala issue. This is the first-time this offer has been released in the United States. Plus, each legal-tender coin is struck in a full ounce of .999 pure silver and has been certified in Gem Brilliant Uncirculated condition by the Numismatic Guaranty Corporation (NGC).

Incredible "First Strike" Specimen—Guaranteed!

Featuring an engaging vignette of a Koala mother and her cuddly cub clinging to her back, each coin has also been certified by the Mint Master at the prestigious Perth Mint to be one of the first 8,000 coins struck. The combination of this one-year-only design and its silver purity as well as the pristine condition and desirable "First Strike" status has collector interest running sky high. Like its Panda counterpart, the Silver Koala coins will feature a new design each year, and this 2008 issue is sure to please collectors worldwide!

Don't Miss Out—Order Now!

A sell-out is expected, so don't miss your chance to acquire this popular, limited-edition silver coin. And if you act now, you can acquire these silver gems at a special issue price as low as $29.95 (+S&H). These coins are sure to have enormous appeal among coin collectors everywhere as well as gift buyers and international travelers on the lookout for treasures that symbolize Australia.

As Low as $29.95

1 – $39.95 each + S&H	5 – $32.95 each + S&H
3 – $35.95 each + S&H	10 – $29.95 each, FREE S&H

30-Day Money-Back Satisfaction Guarantee

Order now while our limited supply lasts. Once these coins are gone, they may never be available again at this low price. Your satisfaction is guaranteed by our 30-day money-back guarantee. Call today to order yours!

1-800-585-9240 ext. 4612

New York Mint • Edina, Minnesota

©2008 Not affiliated with the U.S. Government

NEW RELEASE
One-Year-Only Design
Order Today!

Exclusive U.S. Release from New York Mint:

SOME STEEL IS

MORE AMBITIOUS

THAN OTHERS.

Only Rolex uses 904L steel for its steel watch cases. 904L is a super alloy usually reserved for the chemical industry, where maximum resistance against corrosion is essential. Corrosion resistance stems from 904L's higher chromium content, which forms a thin, impervious barrier on the alloy's surface when exposed to oxygen. In the event of a scratch, the chromium oxide barrier fills and protects it immediately, effectively reducing the scratch's propensity for corrosion. 904L steel is so hard that Rolex even had to develop special equipment to machine it. A mighty 250-ton press is necessary just to stamp out a single Oyster case from a solid block of 904L. When it comes to ensuring the lasting beauty of your watch, no measure is too extreme for Rolex.

ROLEX.COM

OYSTER PERPETUAL EXPLORER II

ROLEX

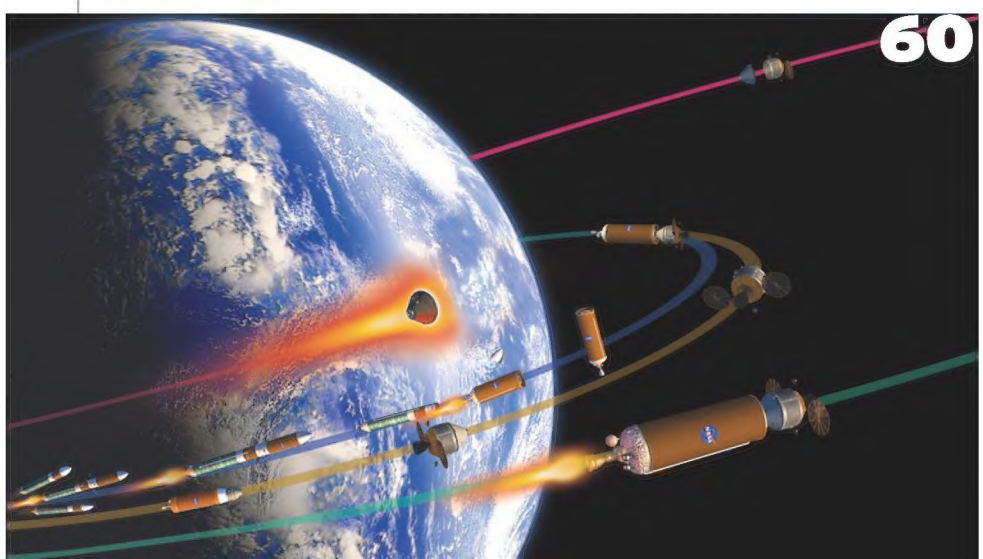
FOR AN OFFICIAL ROLEX JEWELER CALL 1-800-367-6539. ROLEX ♕ OYSTER PERPETUAL AND EXPLORER II ARE TRADEMARKS.
NEW YORK

June/July 2008 | Vol. 23, No. 2

AIR&SPACE
Smithsonian

ON THE COVER: Artist Paul DiMare freezes the moment when two astronauts are about to become the first human beings to explore an asteroid. After a journey of more than two million miles, they've left the spacecraft and continue by jetpack to the rock.

Features


60


30


48

Departments


12 SOUNDINGS

On the Web Site www.airspacemag.com
Read our new Web-only feature on the evolution of the airplane. Our redesigned site now has a searchable archive of every magazine feature published since 2001.

316L STAINLESS STEEL • Ø 43MM • ETA 2893-2 AUTOMATIC MOVEMENT • 2ND TIME ZONE

200M/660FT WATER-RESISTANT • 2 ROTATING BEZELS • LIMITED EDITION OF 500 PIECES

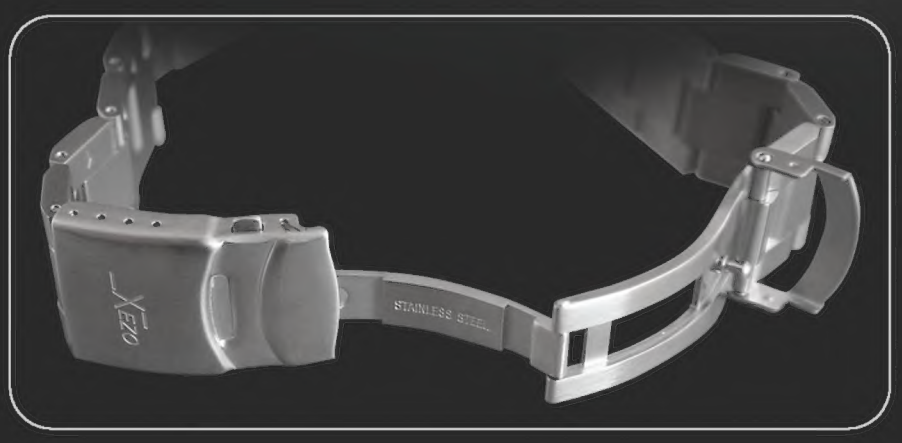
Xezo is now offering the Air Commando limited-edition watch at the below-retail introductory price of $584.00 USD for a limited time. Free shipping to U.S. customers. To order, visit the manufacturer's Web site at **www.Xezo.com** or call (800) 779-0102 within the U.S.

SAPPHIRE CRYSTAL GLASS FRONT & BACK

SILVER FACE:
LUMINOUS HANDS & MARKERS

BLACK FACE:
LUMINOUS HANDS, NUMERALS & MARKERS

The Swiss-made, automatic Air Commando by Xezo is built to last



www.xezo.com

XEZO
Time Evolves™

COURTESY DONALD S. LOPEZ FAMILY

Donald S. Lopez (1923-2008)

DON LOPEZ, who died March 3 following a heart attack at the age of 84, wore heroism lightly. He was a World War II fighter ace who, while flying Curtiss P-40s and North American P-51 Mustangs in China, earned the Distinguished Flying Cross. He also flew F-86s in Korea. Most of us who knew him at the Smithsonian Institution, where he had worked since 1972, eventually becoming the deputy director of the National Air and Space Museum, knew about his war record. We knew also that he'd been a test pilot and an engineer on NASA's Apollo and Skylab programs and that he had played a pivotal role in opening the Museum on the National Mall in 1976. But in the weeks after his death, the stories we shared weren't about those achievements. We talked about the times he had taken us flying. We remembered that he always seemed happy to see us when we stopped by his office, that he asked about our families and told us about his. He was an irrepressible jokester, and we told and retold his jokes. He was a natural teacher, and oh, could he talk airplanes.

It was sometimes hard to square the aggressiveness and single-mindedness that made him an ace with the kindness that characterized his leadership at the Museum. There was never a question, though, that in each role, he had been great. He was, like one of the heroes in Chaucer's *Canterbury Tales*, a very perfect, gentle knight. This issue of *Air & Space* is dedicated to his memory.

The Fifth C?

Cut, Color, Carat, Clarity...Chemistry?

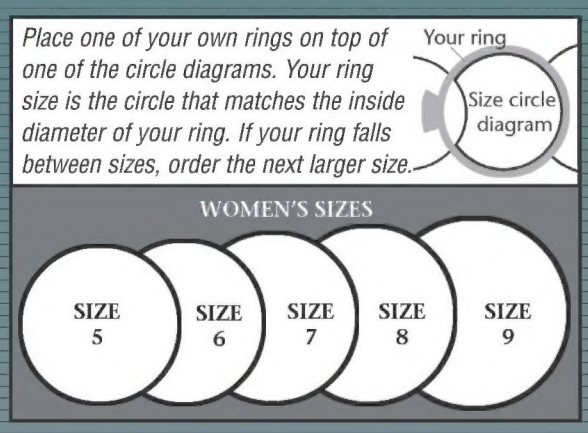
Is it possible that the mind of a scientist can create more beauty and romance than Mother Nature? The laboratories at Diamond*Aura* were created with one mission in mind: *Create brilliant cut jewelry that allows everyone to experience more clarity, more scintillation and larger carat weights than they have ever experienced.* So, we've taken 2.5 carats of our lab-created Diamond*Auras* and set them in the most classic setting—the result is our most stunning, fiery, faceted design yet! In purely scientific measurement terms, the refractory index of the Diamond*Aura* is very high, and the color dispersion is ***actually superior*** to mined diamonds.

Compare For Yourself at 2.5 carats

	Mined Flawless Diamond	Diamond*Aura* Compares to:
Hardness	Cuts Glass	**Cuts Glass**
Cut (58 facets)	Brilliant	**Brilliant**
Color	"D" Colorless	**"D" Colorless**
Clarity	"IF"	**"F" Faultless**
Dispersion/Fire	0.044	**0.066**
2.5 c.t.w. ring	$60,000+	**$145**

Perfection from the laboratory. We named our brilliant cut stones Diamond*Aura*, because, "they dazzle just like natural diamonds but without the outrageous cost." We will not bore you with the incredible details of the scientific process, but will only say that it involves the use of rare minerals heated to an incredibly high temperature of over 5000˚F. This can only be accomplished inside some very modern and expensive laboratory equipment. After several additional steps, scientists finally created a clear faultless marvel that looks even better than the vast majority of mined diamonds. According to the book *Jewelry and Gems–the Buying Guide*, the technique used in Diamond*Aura* offers, *"The best diamond simulation to date, and even some jewelers have mistaken these stones for mined diamonds."*

Place one of your own rings on top of one of the circle diagrams. Your ring size is the circle that matches the inside diameter of your ring. If your ring falls between sizes, order the next larger size.



The 4 C's. Our Diamond*Aura* 3-Stone Classique Ring retains every jeweler's specification: color, clarity, cut, and carat weight. The transparent color and clarity of Diamond*Aura* emulate the most perfect diamonds—D Flawless, and both are so hard they will cut glass. The brilliant cut maximizes the fire and radiance of the stone so that the light disperses into an exquisite rainbow of colors.

Rock solid guarantee. This .925 sterling silver ring is prong-set with a 1.5 carat Diamond*Aura* round brilliant in the center, showcased between two Diamond*Aura* round brilliants of .48 carats each. Adding to your 4 C's, we will include the Diamond*Aura* stud earrings for FREE! Try the Diamond*Aura* 3-Stone Classique Ring for 30 days. If for any reason you are not satisfied with your purchase, simply return it to us for a full refund of the purchase price and keep the stud earrings as our gift.

Not Available in Stores

Diamond*Aura* 3-Stone Classique Ring
(2.5 c.t.w) • **$145** + S&H

FREE *stud earrings with purchase of Classique Ring—a $59.95 value!*

Available in ring sizes 5-9

Call to order toll-free, 24 hours a day, 7 days a week.

1-888-201-7095

Promotional Code DAR265-01
Please mention this code when you call.

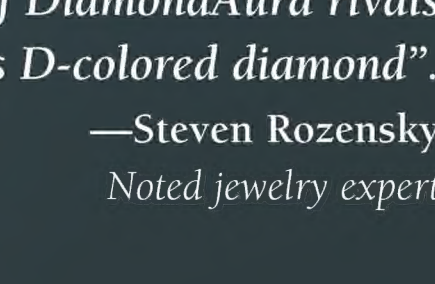
Stauer
Heritage of Art & Science
14101 Southcross Drive W., Dept. DAR265-01
Burnsville, Minnesota 55337

Visit us online at www.Stauer.com for the complete line of Stauer Watches, Jewelry and Collectibles

"The color and clarity of DiamondAura rivals that of a flawless D-colored diamond".

—Steven Rozensky

Noted jewelry expert



Receive these scintillating Diamond*Aura* Classique sterling silver stud earrings FREE!

Read details left.

For fastest service, call toll-free 24 hours a day 888-201-7095

Viewport

FROM THE DIRECTOR

A Visit to Remember

AT THE NATIONAL AIR AND SPACE Museum, we are in the memory business. By commemorating past successes, we hope to inspire future ones. And of course we want visitors to remember the time they've spent with us. To accomplish these goals, we use powerful memory aids we call Discovery Stations.

Discovery Stations, carts that can be placed almost anywhere in the Museum, are portable learning tools built around a touchable artifact or hands-on activity. Most objects in the Museum are priceless historic artifacts that can't be touched, but Discovery Stations use items that visitors can experience (see In the Museum, "Welcome Discovery," p. 17). Wearing period aviation clothing or a spacesuit glove, examining the "oldest rock you will ever touch," or twisting a box to discover, as did Wilbur Wright, how wings could be warped to control flight are the kinds of experiences young visitors are more likely to remember.

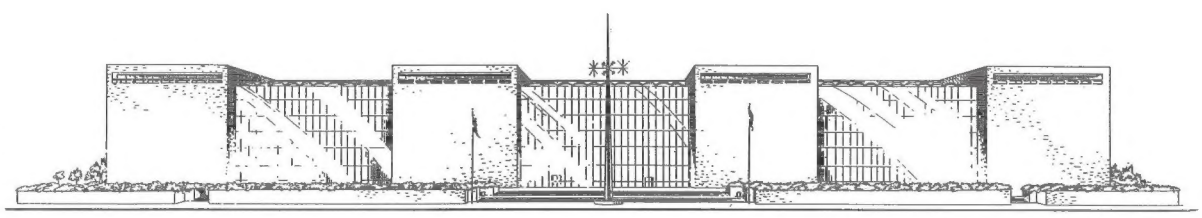
To make these hands-on opportunities even more meaningful to visitors, we have recruited volunteer station operators who are trained to guide the process of discovery. These volunteers ask questions that help visitors find answers rather than simply describe an object or explain its history. Many of the station operators are high school students, who are learning the difference between instruction that is fun as opposed to simply memorizing facts and figures. We believe our high school volunteer operators enhance the experience for younger visitors. Youngsters identify with them and communicate with them as peers rather than as authority figures. Operators are trained to work not only with young people, however, but with visitors of all ages.

The focus of the Discovery Station experience is not the transfer of knowledge; there is not enough time for that. Our aim is to present artifacts or galleries in an engaging way, leading the visitor to decide that the topic is worth further investigation, long after the Museum encounter is over.

Discovery Stations and the use of hands-on exhibits to support Museum learning are becoming an integral part of exhibition and gallery design at the National Air and Space Museum. We developed Discovery Station lessons, for example, as part of the design of two galleries: "The Wright Brothers and the Invention of the Aerial Age" and "America by Air." We built into both galleries Discovery Station-like features that visitors can manipulate. Now visitors can feel the same clues for flight control by wing warping that Wilbur Wright discovered, see how flight controls operate and have changed with time, and enjoy many other learning experiences directly related to specific gallery themes.

Although many artifacts are not available for visitors to handle, Discovery Stations contain materials that move some exhibits from "Look, but don't touch," to "Look, touch, learn, and remember!"

J.R. DAILEY IS THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



AIR&SPACE Smithsonian

Editor Linda Musser Shiner
Executive Editor Paul Hoversten
Senior Editors Tony Reichhardt, Patricia Trenner
Senior Associate Editor Perry Turner
Associate Editors Michael Klesius, Rebecca Maksel, Diane Tedeschi
Photography and Illustrations Editor Caroline Sheen
Researcher Roger A. Mola
Graphic Design Ted Lopez, Eason Associates, Inc.
Founding Editor George C. Larson

CONTRIBUTING EDITORS

Roger Bilstein, William E. Burrows, Eric Chaisson, Tom Crouch, David DeVorkin, Freeman Dyson, Daniel Ford, Greg Freiherr, Donald Goldsmith, George Greenstein, William Gregory, Dan Hagedorn, R. Cargill Hall, Richard Hallion, Jim Hansen, Gregg Herken, Nick Komons, W. David Lewis, Eric Long, Stephen Maran, Laurence Marschall, Ted Maxwell, Marshall Michel, Ron Miller, Brian Nicklas, James Oberg, Dominick Pisano, Robert E. Pollack, George Robinson, Chad Slattery, Marcia Smith, Robert W. Smith, Jill Tarter, G.L. Verschuur, Stephan Wilkinson

EDITORIAL: (202) 633-6070
e-mail: *editors@si.edu*
Web site: *www.airspacemag.com*

Air & Space/Smithsonian; June/July 2008; Volume 23, Number 2

Air & Space/Smithsonian (ISSN 0886-2257) is published bimonthly by Smithsonian Business Ventures, MRC 513, PO Box 37012, Washington, DC 20013-7012. Periodical postage paid at Washington, DC, and additional mailing offices.

POSTMASTER: Send change of address to *AIR & SPACE/Smithsonian*, PO Box 420113, Palm Coast, FL 32142-0113. Printed in the USA. Canadian publication agreement no. 40039324. Canadian return address: Brokers Worldwide, PO Box 1051, Fort Erie, ON L2A 6C7 Canada.

We may occasionally publish extra issues. ©Smithsonian Institution 2008. All rights reserved. Reproduction in whole or in part without permission is prohibited. Editorial offices: MRC 513, PO Box 37012, Washington, DC 20013. Circulation and advertising offices: 420 Lexington Ave., New York, NY 10170.

Subscription Prices: U.S. and possessions: $26 a year payable in U.S. funds. Canada and all other countries: add $6.00 (U.S. funds) per year. Ninety-nine percent of dues is designated for magazine subscription. To purchase an issue (current $4.99, back issue $7), please write *AIR & SPACE/Smithsonian*, 420 Lexington Ave., Suite 2335, New York, NY 10170, or call (212) 916-1379.

Mailing Lists: We sometimes make our subscriber list available to companies that sell goods and services that we believe would interest our readers. If you do not want to receive such mailings, send your current mailing label or, an exact copy, to: *AIR & SPACE/Smithsonian*, Mail Preference Service, PO Box 420113, Palm Coast, FL 32142-0113.

Address Changes and Subscription Orders: mail to *AIR & SPACE/Smithsonian*, PO Box 420113, Palm Coast, FL 32142-0113; call (800) 766-2149; outside the U.S., call (386) 447-2721.

He was a hardworking farm boy.

She was an Italian supermodel.

He knew he would have just one chance to impress her.

The fastest and easiest way to learn ITALIAN.

Arabic • Chinese (Mandarin) • **Danish • Dutch • English** (American) • **English** (British) • **Farsi** (Persian) • **French • German • Greek**
Hebrew • Hindi • Indonesian • Italian • Irish • Japanese • Korean • Latin • Pashto • Polish • Portuguese (Brazil) • **Russian**
Spanish (Latin America) • **Spanish** (Spain) • **Swahili • Swedish • Tagalog** (Filipino) • **Thai • Turkish • Vietnamese • Welsh**

Discover a whole new world with Rosetta Stone,® the world's leading language-learning software. Only Rosetta Stone uses Dynamic Immersion® to teach you a language quickly and efficiently, without tedious translation and grammar drills.

- You'll experience our **Dynamic Immersion** as you match real-world images to words spoken by native speakers. There is no translation or memorization. Instead, you become quickly engaged, the way you learned your first language... for a faster, easier way to learn.
- Our patent-pending **Voice Recognition Technology** evaluates your speech and coaches you to more accurate pronunciation, so you'll be speaking faster and more naturally.
- And only Rosetta Stone has **Adaptive Software** which tracks your progress and then customizes every lesson based on your individual needs, for faster and more effective fluency.

Discover Rosetta Stone - **The Fastest Way to Learn a Language. Guaranteed.™**

100% GUARANTEED
SIX-MONTH MONEY-BACK

SAVE 10%

Level 1	~~$209~~	**NOW**	**$188.10**
Level 1&2	~~$339~~	**NOW**	**$305.10**
Level 1,2&3	~~$499~~	**NOW**	**$449.10**

©2008 Rosetta Stone Ltd. All rights reserved. Patent rights pending. Discount offer not to be combined with other offers, and subject to change without notice. Six-Month Money-Back offer is limited to purchases made directly from Rosetta Stone and does not include return shipping.

Call
(866) 342-9449

Online
RosettaStone.com/ais068

Use promotional code ais068 when ordering.
Offer expires October 31, 2008.

RosettaStone®

Letters

WRITE TO US

The Multi-Tasking Maytag

The letter in the last issue on the origins of the Ryan PT-22 nickname "Maytag Messerschmitt" ("New Recruit," In the Museum, Feb./Mar. 2008) made me recall that before World War II, Maytag manufactured a washing machine with a gas engine for farm families that lived where electric power was unavailable. As boys, we used to take the engines out of worn-out washing machines and install them on our bicycles. The PT-22 Kinner engine sounded exactly like the engine on the Maytag washing machine.

Major Taylor B. McKinnon
U.S. Air Force (ret.)
San Bernardino, California

Who Says a Magazine Can't Be Clean?

I was disappointed to see profanity used in "Who Says a Jet Can't Be Cheap" (Feb./Mar. 2008). No, I don't care that it was in a quotation. I realize the language of our culture has become coarser over the years, but I never expected *Air & Space/Smithsonian* to join in.

Greg Meyer
Elk Grove Village, Illinois

Little Bitty but Tough as Nails

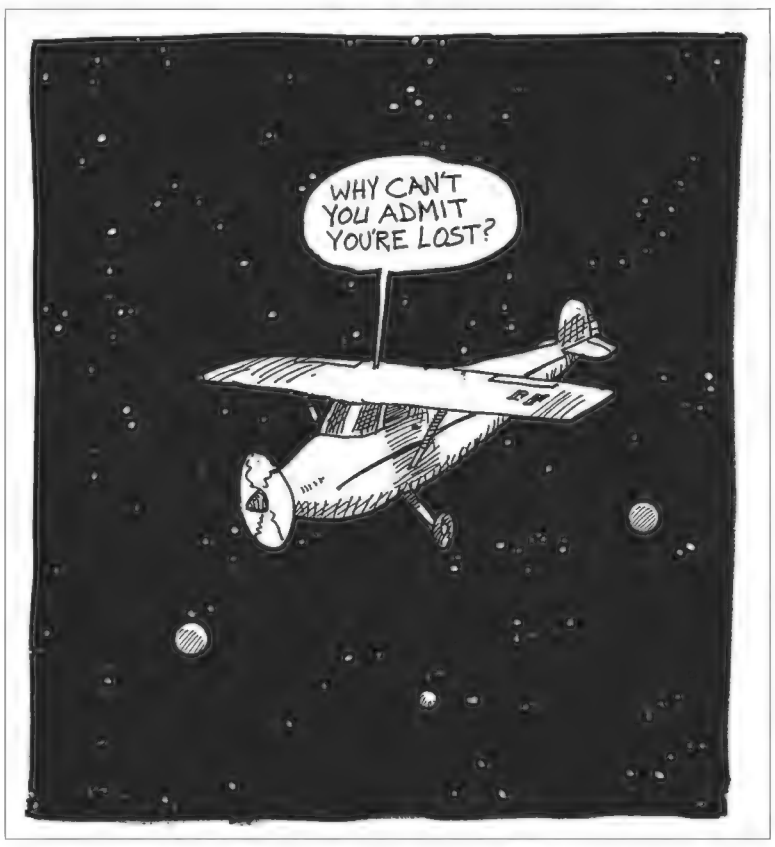
I took offense to the statement that the Citabria is "a little bitty airplane that you could pull the wings off with your bare hands" ("Anatomy of a Search," Feb./Mar. 2008). The Citabria is an aerobatic aircraft designed for 6 Gs positive and 5 Gs negative. The Citabria that Steve Fossett was flying was stronger than the Civil Air Patrol Cessna 182s that were looking for him.

Philip DeBarola
Safford, Arizona

Three Three-Wing Craft?

The letter in the Feb./Mar. 2008 issue about a second triplane reaching the front in World War I called to mind a third triplane that may have gotten there as well ("What the Red Baron Never Knew," Dec. 2007/Jan. 2008). In *The Fighting Triplanes*, Evan Hadingham reports that the Pfalz Dr.1 triplane was tested by several World War I pilots, including Manfred von Richthofen (the Red Baron), and includes several photographs of von Richthofen and others with the aircraft. Von Richthofen was impressed by its performance, and as a result, 10 were produced; nine were sent to the front for evaluation. However, I have found no report on the aircraft's service or performance in war.

Steve Slayton
Gig Harbor, Washington



GEORGE JARTOS

Fleeting Sensations

While visiting my son at Schofield Barracks in Hawaii in 1991, we decided to go skydiving at Dillingham Field on the north shore of Oahu. A biplane was in the area, and I persuaded the pilot

AIR&SPACE Smithsonian

Smithsonian Institution

PUBLISHING GROUP

President	Thomas Ott
Executive Asst. to the President	James A. Babcock
General Manager	Alan Chu
Group Publisher	Kerry Bianchi
ADVERTISING	(212) 916-1300
Ad. Services Manager	Marilyn Cruz
New York	Diantha W. Redd, Sales Director, Suzanne Grossman
Midwest	Bill Milligan, Lara Esquivel, Jeff Orr
Detroit	Colleen Maiorana, Holly Wilcox
Southwest	Steve Moynihan, Lindsay Davis
Southeast	Kelly Hediger
West Coast	Kate Knox, Charles Carroll
Mid-Atlantic	Christine Hoisington
Florida	Colleen Schoch
Caribbean/Cent. Amer.	Al Nadal
Mexico	Elsie Mendez Eriquez, Victor Ocadiz
Canada	Richard Brown, Cindy Ratych, David Seaberg, Greg M. Smith
London	Graeme Brown
Japan	Yoshinori Ikeda, Shigenori Nagatomo
Thailand	Yvan Van Outrive, Ja Pipatra
Korea	S.S. Song
Direct Response	MI Media Services, LLC
Interactive	Andrea Basche
Advertising Assistants	Blythe Graham-Jones, Amanda ReCupido

MARKETING/RESEARCH

Director of Marketing	Rosie Walker
Associate Art Director	Natalie Thompson
Assoc. Dir. of Sales Development	Christine Staley Corr
Marketing Manager	Laurie A. Corson
Promotion Manager	Karen Mendolia
Assoc. Marketing Mgr.	Caitlin McCarthy
Research Director	Renee Mitchell
Research Manager	Marilyn Resciniti

CONSUMER MARKETING

Circulation Director	Lisa Dunham
Planning Director	Elizabeth M. Hopkins
Fulfillment Director	Andrea Sole
Forecast Manager	Donald G. Dodd
Purchasing Manager	Suzanne L. Eng
Direct Mail Manager	Lori Paldino
Renewals and Gift Dir.	Miriam Johnson
Gift Manager	Joanne Marrero
Renewals and Billing Coordinator	Benjamin Shields
Direct Mail Coordinator	Laura E. Vichick
Circulation Operations Specialist	Eve Mormino

ONLINE PUBLISHING GROUP

Director	Emily Allen
Sr. Web Producer	Kelly Durkin
Interactive Marketing Manager	Paula K. Burley
Interactive Ad Operations Coordinator	Matthew Feldman
Jr. Producer	Cheryl Carlin

MANUFACTURING

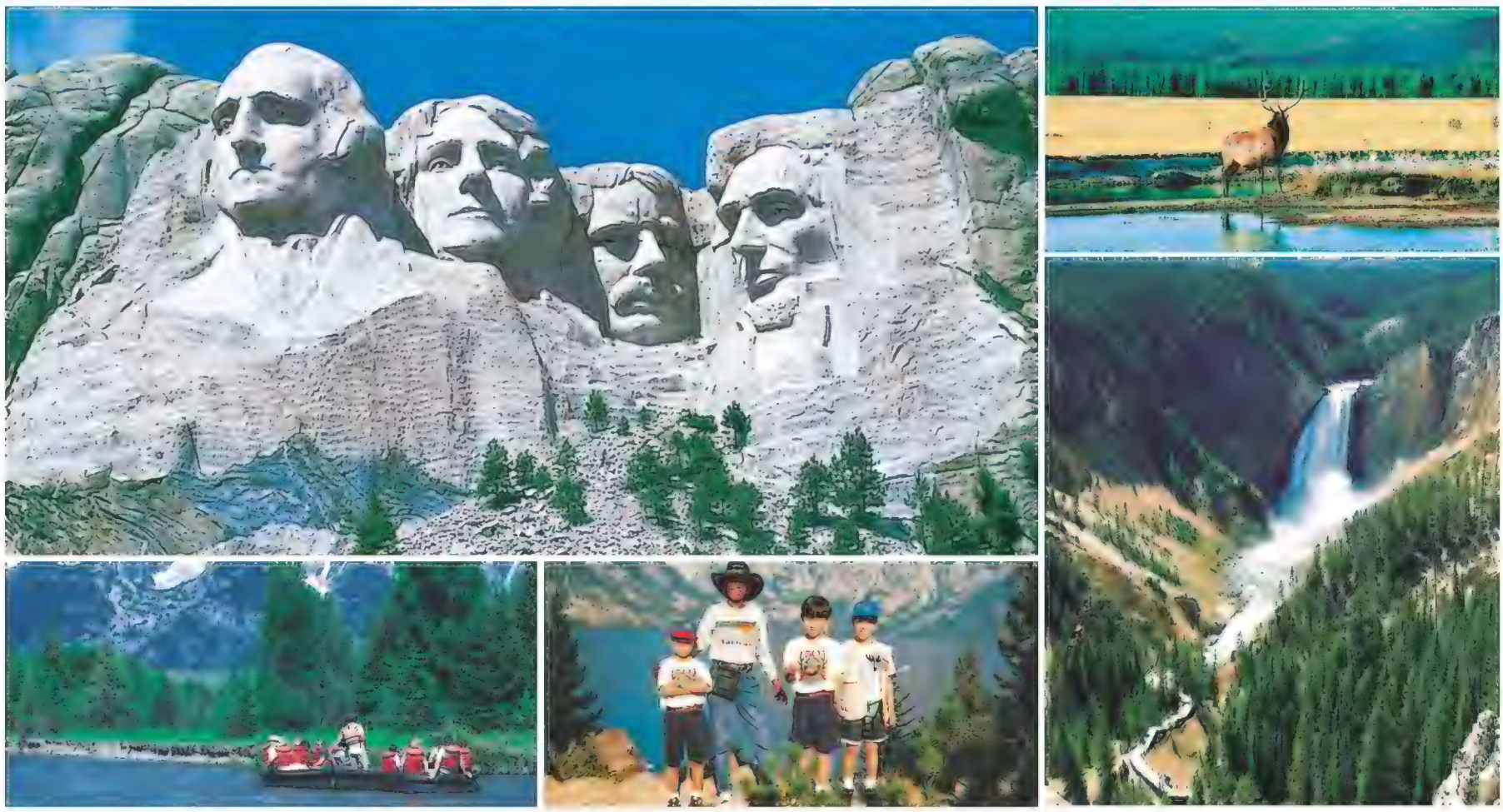
Director	Sarah D. Kingsley
Postpress Director	Greg Williams
Prepress Director	Katherine Balch
Prepress Manager	Frank Matthew Hale II
Prepress Manager	Marie Prete
Contributing Color Analyst	Steven Schwacke
Color and Quality Mgr.	Stanley Boone
Adv. Systems Manager	Penie Atherton-Hunt

BUSINESS OFFICE

Business Manager	Ed Dequina
Accountant	Beth Cunigan

SMITHSONIAN BUSINESS VENTURES

Acting Chief Executive Officer	Thomas Ott



Clockwise starting top left: Mt. Rushmore, Yellowstone Park, Yellowstone Falls, Jenny Lake, floating on Snake River beneath the Grand Tetons

$995 Yellowstone Park and Mt. Rushmore 8 Days

Call Now for Good Dates and Best Price

Caravan makes it so easy - and so affordable - for you and your family to explore the rugged mountains, open country, and invigorating culture of Yellowstone Park and Mt. Rushmore. **Your Caravan 8 day tour includes nearly everything**, including most meals and all activities, hotels, airport transfers, and transportation and excursions within this 8 day tour.

Click to Caravan.com for highly detailed Yellowstone Park and Mt. Rushmore tour information, including weather, tour videos, airport transfers, client comments, hotel photos and frequently asked questions.

Join the smart shoppers and experienced travelers who rely on Caravan to handle all the details while you and your family enjoy a well-earned, worry-free vacation in America's national parks. Or, choose from any one of our other tours, starting at just $995. **Call Today — Pack Your Bags–Relax and Enjoy.**

"I've several times mentioned the **attractive price of $995** per person plus airfare for a 10-day, fully-escorted trip to Costa Rica offered throughout the year by the **distinguished** Caravan Tours. Caravan is now offering the very same $995 plus airfare for similar 8-day or 10-day tours of Mexico, Guatemala, Mount Rushmore and Yellowstone, Canada, the California Coast, and more ... highly affordable vacations."
— Arthur Frommer, Travel Writer

"My family enjoyed all that we did in such a short period of time. We would have never been able to do it all on our own. Would definitely do another Caravan tour!"
— (Client), Freehold, New Jersey

"Caravan is ... very reasonably priced"
— New York Times

All Tours From $995 to $1195

9 days	Canadian Rockies and Glacier Park
8 days	Nova Scotia and Prince Edward Island
8 days	Grand Canyon, Lake Powell Zion, Bryce
8 days	**Yellowstone, Mt. Rushmore and Grand Tetons**
8 days	California Coast and Yosemite Park
8 days	New England Fall Colors
8 days	Mexico's Ancient Cultures
8 days	Mexico's Copper Canyon Round Trip Train
10 days	Costa Rica Natural Paradise
11 days	Guatemala with Tikal and Copan

#1 Travel Value. Fully Escorted Tours Since 1952

Caravan.

Call Now For Your FREE 28-Page Information Guide

1-800-Caravan Caravan.com

ALL TOURS FROM $995 TO $1195 PER PERSON, DOUBLE OCCUPANCY, PLUS TAXES AND FEES.

Letters

to give me a brief ride and let me jump from the plane. It was originally a Fleet Model 1 ("Restoration: Fleet Model 8," Dec. 2007/Jan. 2008). Before I jumped, we did several stalls, rolls, and lazy eights. In that open cockpit over the blue Pacific, I realized what flying was all about.

Jennings B. Siegriend
Fayetteville, North Carolina

A Faint, Fruity Essence

"Second, But Still Up" (In the Museum, Apr./May 2008) states that the Vanguard satellite showed that "Earth is more pear-shaped than round." Earth is very close to round. The southern mid-latitudes are an average of just 30 feet wider than the northern mid-latitudes.

Thomas D. Jones
former astronaut
via e-mail

Spitfires: Easier on the Eyes

"Best of the Battle of Britain" (Feb./Mar. 2008) reminded me of an interesting side story. During World War II, Sir Harold Ridley, a British ophthalmologist who treated Royal Air Force pilots for combat injuries, made a startling discovery. When the glass cockpit canopy of the Hurricane was hit by bullets, it shattered. If the pilot was not wearing goggles, tiny slivers of glass would often penetrate his eyes. The slivers were impossible to remove, and they would sometimes cause blindness.

The cockpit canopy of the Spitfire, on the other hand, was fabricated of a plastic called Perspex CX. If the Spitfire canopy was shattered and pieces of Perspex were embedded in the pilot's eyes, they did not act as foreign bodies and were actually tolerated. Blindness did not result.

In 1980, the U.S. Food and Drug Administration approved the use of Perspex for intra-ocular transplants. In cataract surgery today, replacement lenses are made of Perspex CX.

Ray S. Krug
Lakewood, Colorado

A Question of Power

"Mission Unaccomplished" (Above & Beyond, Apr./May 2008) states that the C-97 had the same engines as the B-29. The B-29 was powered by the Wright R-3350 Duplex Cyclone, while the C-97 had the higher-horsepower R-4360 Pratt & Whitney Wasp Major.

Clint Royce
Layton, Utah

Editors' reply: For most of its career the B-29 did use the R-3350. However, at the end of World War II, some of the very last models of the B-29 used the 4360 engine.

Corrections

Apr./May 2008 "Second, But Still Up," In the Museum: The long duration of Vanguard's orbit is due to its high altitude, not its solar cells.

Feb./Mar. 2008 "Best of the Battle of Britain": Spitfire JG891 crashed on Kiriwina, part of the Trobriand Islands, not in the Solomon Islands.

"Air America's Black Helicopter": The photograph on p. 67 should have been credited to Dick Casterlin.

WRITE TO US at Letters, *Air & Space/Smithsonian,* MRC 513, P.O. Box 37012, Washington, DC 20013. Please type or print clearly. You must include your full address and daytime phone number.

e-mail: *editors@si.edu*. All e-mails must include your full name, mailing address, and daytime phone number.

Air & Space is not responsible for the return of unsolicited materials. Never send unsolicited original photographs to the Letters department; send only copies.

All letters selected for publication are edited. We reserve the right to publish letters in the magazine, on our Web site (*www.airspacemag.com*), or both. We regret that we cannot respond to every letter.

AIR&SPACE Smithsonian

Smithsonian Institution

Acting Secretary
Cristián Samper

Director, National Air and Space Museum
General John R. Dailey, USMC (ret.)

SMITHSONIAN BOARD OF REGENTS

Chief Justice of the United States
John Roberts, Chancellor

Vice President of the United States
Richard B. Cheney

Appointed by the President of the Senate
Hon. Thad Cochran
Hon. Christopher J. Dodd
Hon. Patrick J. Leahy

Appointed by the Speaker of the House
Hon. Xavier Becerra
Hon. Sam Johnson
Hon. Doris Matsui

Appointed by Joint Resolution of Congress
Mr. Eli Broad
Dr. Phillip Frost
Dr. Shirley Ann Jackson
Mr. Robert P. Kogod
Mr. Roger W. Sant
Mr. Alan G. Spoon
Ms. Patricia Q. Stonsifer

SMITHSONIAN NATIONAL BOARD

Mr. L. Hardwick Caldwell III, *Chair*
Mrs. Peggy Paulson Burnet, *Vice Chair*
Mr. Peter H. Lunder, *Vice Chair*
Mr. Paul Neely, *Vice Chair*

National Board
Mrs. Claudia Ream Allen, Ms. Valerie Anders, Mrs. Judy Hart Angelo, Mrs. Barbara Barrett, Ms. Jane Lipton Cafritz, Dr. Wilmer S. Cody, Mr. James F. Dicke II, Mr. John G.B. Ellison Jr., Ms. Sakurako D. Fisher, Mr. Michael R. Francis, Mr. Bradford M. Freeman, Mr. John French III, Mrs. Shelby M. Gans, Mr. Richard W. Herbst, Ms. Irene Y. Hirano, Mr. Steven G. Hoch, Mrs. Judy Huret, Mr. Robert E. Keith Jr., Mr. Robert E. Long Jr., Mr. Robert D. MacDonald, Mr. Chris E. McNeil Jr., Mr. Gary B. Moore, Mr. Morris W. Offit, Mr. Russell E. Palmer Jr., Ms. Judy Lynn Prince (ex-officio), Mr. William M. Ragland Jr., Hon. Ronald A Rosenfeld, Mrs. Theiline P. Scheumann, Mrs. Marna Del Mar Schnabel, Hon. Rodney E. Slater, Mrs. Beatrice R. Taylor, Mr. Douglas C. Walker, Mr. Mallory Walker

Honorary Members
Mr. Robert McC. Adams, Mr. William S. Anderson, Hon. Max N. Berry, Mr. Richard P. Cooley, Mr. Frank A. Daniels Jr., Mr. Charles D. Dickey Jr., Mrs. Patricia Frost, Mr. Alfred C. Glassell Jr., Mr. I Michael Heyman, Mr. James M. Kemper Jr., Mrs. Jean B. Mahoney, Justice Sandra D. O'Connor (ret.), Mr. Francis C. Rooney Jr., Mr. Wilbur L. Ross Jr., Mr. Lloyd G. Schermer, Hon. Frank A. Weil, Mrs. Gay F. Wray

Advertisement

We Apologize That It Loses 1 Second Every 20 Million Years

First Super Light Titanium Timepiece Under $200 With Precision to 1 Billionth of a Second.

The U.S. government has engineered the most ingenious, most accurate clock in the world: the F-1 U.S. Atomic Clock in Boulder, Colorado. Our extraordinary new Stauer Titanium Atomic Watch utilizes the transmissions directly from that remarkable cesium fission atomic clock to report the most precise time. This scientifically advanced timepiece will gain or lose only one second over a 20 million-year period. It is that accurate! This perfectly tuned technological invention with the super light strength of titanium is now available for UNDER $200.

Super Light Titanium has two big advantages over steel. One is corrosion resistance and the other is that titanium has the highest strength-to-weight ratio of any metal, which means that titanium is approximately 45% lighter than steel. But every other titanium watch that we can find is priced at over $400, and none of those are nearly as accurate as our atomic movement. Stauer has decided to bring these resources together in a timepiece that has the most accurate movement available today. You'll never have to set this watch. Just push one of the buttons and you are synchronized with the atomic clock in Colorado, and the hands of the watch move to the exact time position. The sleek black textured dial has luminous hands and markers plus the timepiece is water resistant to 3 ATM.

A Titanium-clad offer. This Titanium Atomic Watch exceeds the accuracy of any Swiss luxury automatic so you can be more punctual and keep most of your money in your wallet, not on your wrist. Look at your watch and we guarantee that the time is incorrect, unless you are wearing the advanced atomic technology.

The Stauer Titanium Atomic Watch is not available in stores and it comes with our 30 day money-back guarantee. If you're not completely satisfied with the accuracy, simply return the watch for the full purchase price.

M.S.R.P. $595. Now $195

Not Available in Stores

Stauer Titanium Atomic Watch $195 +S&H or
4 credit card payments of $48.75 +S&H

Call Toll-Free now to take advantage of this limited offer.

1-888-201-7141

Promotional Code TTA152-03
Please mention this code when you call.

To order by mail, please call for details.

Stauer
Heritage of Art & Science

14101 Southcross Drive W.,
Dept. TTA152-03
Burnsville, Minnesota 55337
www.stauer.com

Rockets in the Tropics

ON THE NIGHT of March 9, tucked between Brazil and Suriname in the French Guiana rainforest, reporters and dignitaries from the European Union gathered under a large wooden canopy for a glimpse of Europe's future in space. Just three miles away, flanked by lush palm trees, stood a massive Ariane 5 rocket. Under its payload fairing was the Automated Transfer Vehicle, a barrel-shaped spacecraft that will function as a gas tanker, delivery truck, and garbage hauler for the International Space Station.

©2008 ANATOLY ZAK/RUSSIANSPACEWEB.COM

An Ariane 5 rocket, carrying the Automated Transfer Vehicle, stood tall in a final assembly building before rollout to the launch pad.

When the Ariane 5, the crown jewel of European engineering, ignited, it turned night into day before disappearing into the low clouds, carrying the first transport ship to access the space station from a site other than Florida's Cape Canaveral or the Russian spaceport in Kazakhstan. The ATV docked with the station on April 3.

In 2004, the United States announced its decision to retire the space shuttle in 2010 and leave the station business altogether a few years later. With the loss of the shuttle's cargo capacity, the ATV, previously slammed for being overweight and overpriced, emerged as a high-volume supply line to the station. "It is not simply an important vehicle for Europe but for all station partners," said Jean-Jacques Dordain, the director general of the European Space Agency, to guests in the Guiana Space Center's Jupiter control building.

Rocketry has been the pride of French Guiana since the 1970s, when the European space program began. Today, the first thing visitors at Cayenne's

FROM THE CRITICS

Aeroglyphics

AMERICAN ARTIST CHARLES COHAN has fashioned an exhibit of iconic representations of runways and airport terminals – like the ones in the back pages of inflight magazines – which recently was on display at a Washington, D.C. art gallery, Curator's Office. In a monograph on Cohan, art historian Jaimey Hamilton writes, "A real sense of the passage of space and time between these airports is replaced by a regularized and deterritorialized grid. The result is a representation of our confused and dispersed postmodern geography.... [T]he steady repetition and the confusion of scale calls attention to the way that (post) modernity has regulated and enforced the multiple...in terms of the mass manufacture of vernacular architecture."

Ummm...okay. Our critic says, "Wow. Cool."

CHARLES COHAN

RON KAPLAN

Frank Schelling's 1918 Curtiss JN-4H won the 2006 National Aviation Heritage Trophy and the People's Choice Award.

HEADS UP

Great Restorations

OWNERS OF VINTAGE AIRCRAFT who wish to enter the National Aviation Heritage Invitational should submit an application before August 29. The competition, which is sponsored by Rolls-Royce, the National Air and Space Museum, and the Reno Air Racing Foundation, names winners in four categories; the most popular, the People's Choice Award, is selected by visitors to the Reno Air Races in Nevada, held this year from September 10 to 14. "We're limited in the number of aircraft we can hold on the ramp," says invitational director Ken Perich, "so for planning purposes we'd like to receive applications as soon as possible." Visit *www.heritagetrophy.org* or call (775) 852-9307.

Rochambeau airport see—along with posters urging them to get vaccinated against mosquito-borne yellow fever—is a display of Ariane launchers.

Visitors to Kourou, which serves as the spaceport's residential area, wake up to a cacophony of exotic birds. From Kourou, a two-lane road runs through wetlands and bursts into what looks like the set of a sci-fi movie: futuristic buildings, helicopter pad, and a 130-foot replica of an Ariane 5 rocket. Machine gun-wielding paratroopers guard a fence, behind which rainforest competes for skyline with communications antennas, rocket assembly buildings, and launch towers.

Behind Ariane's current launch facilities, a long stretch of excavated mud cuts through the jungle toward new construction. A road zigzags through the wilderness to a giant amphitheater-shaped flame pit topped with a concrete platform on two pillars—the launch complex for the Russian Soyuz rocket.

Officially, the Soyuz is coming to Kourou to launch the commercial satellites that are too light for the heavy-lifting Ariane 5. However, Russian engineers, who expect to complete pad construction next year, say the spaceport could easily be upgraded to support manned missions.

The European Space Agency recently renewed its interest in the Ariane 5 as a launcher of a next-generation manned spacecraft. If Europe commits to "man-rating" its flagship rocket, Kourou might get yet another launch pad. ESA officials have hinted that a long stretch of coastal land reserved within the Guiana Space Center can accommodate more pads, and current launch facilities were designed not to block any future expansion.

ANATOLY ZAK

IN MEMORIAM

DAN PATTERSON

RON DICK, who served in the Royal Air Force for 38 years and retired in 1988 with the rank of Air Vice Marshal, died of cancer last March 25 at age 77. He logged some 5,000 hours in more than 60 types of aircraft, from Tiger Moths (pictured) to the arrow-like Vulcan, and was a Smithsonian International Fellow as well as a consulting editor for this magazine.

Aviation's renaissance man, he was also "beyond handsome," says archivist Brian Nicklas of the National Air and Space Museum. "When he came to the Museum, women on the staff literally swooned. It was even worse when he arrived at a formal event in his air vice marshal uniform."

Dick was also a lecturer on military history for Smithsonian Associates, the U.S. Air Force Air University, and Holland/America Cruise Lines. He wrote or co-wrote 13 books, won two aerobatic trophies, and loved classical music, opera, and bird-watching.

The Flying Reindeer

DEPARTMENT OF DEFENSE

The Caribou entered the Army as a CV-2 but retired as a U.S. Air Force C-7.

»» THIS JULY 30 will mark the 50th anniversary of the first flight of the de Havilland Caribou, an airplane that once knocked the socks off the U.S. Army.

During the Korean War, two bushplanes made by de Havilland of Canada—the Beaver, and later the Otter—served the U.S. Army with distinction. So when the company was seeking a follow-up success to these flying jeeps, its executives took marketing trips to Washington in the mid-1950s and learned what the Army wanted next: a three-ton tactical short-takeoff-and-landing transport with rear loading. After a hurried but breakthrough design, the Caribou took shape.

In the late 1950s, de Havilland launched a promotion blitz: seven months, 40 countries, 154 airports, and 470 demo flights in the worst terrain it could find. In 1961, the U.S. Army took delivery of 22 (it eventually ordered 159) and sent them to South Vietnam. (The Caribou also found homes in Canada, Australia, Spain, Colombia, and India.)

In the early 1960s, six squadrons served with the 834th Air Division, then transferred to the 483rd Tactical Airlift Wing at Cam Ranh Bay with its 900-foot airstrip. Pilot John Parsons remembers aborting a takeoff and running out of runway. "There was a dirt road which angled off to the left and led down a slight incline to a Vietnamese hamlet," he says. "I turned the airplane down onto the road. Villagers were scattering like mad. We came to a stop in the middle of the hamlet with the wings hanging out over the roofs of the hooches."

Lu Mays, another Army Caribou jock, had a more pleasant experience. "I was on a team that picked up two Caribou and flew them to Fort Rucker [in Alabama] for a 1,000-hour evaluation," he says. "The flight included a delivery of two baby caribou to the St. Louis Zoo."

GRAHAM CHANDLER

UPDATE

First Stealth Fighter to Go Public

LAST MARCH, personnel from the 410th Flight Test Squadron towed Scorpion 4, the fourth pre-production model of the Lockheed Martin F-117A Nighthawk stealth fighter, to its new home at the Air Force Flight Test Center Museum's Blackbird Airpark in Palmdale, California. It roosts with other Lockheed products, including a U-2, a D-21B drone, the original Mach-3-capable A-12, and its final variant, the SR-71.

First flown in July 1982, Scorpion 4 served as a test aircraft its entire career, beginning with measurements of radar cross-section and infrared signature. Other flights included trials of the airplane's infrared target acquisition and designation capabilities and a Navy review to see if the F-117A would be suitable for aircraft carriers. The aircraft also tested night-vision goggles, a low-observable communications antenna, radar-absorbent coating, improved braking systems, and an experimental camouflage paint scheme for daylight operations. The airplane was retired in March 2007 with 2,464.6 flight hours. The entire F-117 fleet is scheduled to retire by the end of the year (see "Unconventional Weapon," Dec. 2007/Jan. 2008).

To prepare the airplane for display, volunteers from the 410th Flight Test Squadron removed all radar-absorbent coatings and structures as well as classified equipment, then fabricated replacements using unclassified materials.

The first declassified photo of a Nighthawk, revealed at a November 1988 Pentagon press briefing, was a single dark, grainy image of Scorpion 4.

PETER W. MERLIN

PETER W MERLIN

The F-117 Scorpion 4 can sting no more, but it makes a sinister addition to Blackbird Airpark.

Hail a Jet

»» JEFFREY PHILLIPS, a real estate developer from Boca Raton, Florida, recently logged his 50th flight as a passenger on Dayjet, the new "on-demand, per seat" regional air taxi service. Launched last October, Dayjet is currently flying 10 three-passenger Eclipse 500 very

light jets among 35 mid-size cities in Florida and the Southeast. "Dayjet works beautifully for me," says Phillips, who's on a first-name basis with the company's pilots. "It gets me home for dinner."

In six months of operation, Dayjet, the brainchild of Ed Iacobucci, a former software entrepreneur, has signed up 1,500 customers and is averaging 15 to 20 flights per day. The company offers customized small-jet travel among cities with little or no airline service, at per-mile fares comparable to those of airline business class.

The Dayjet business plan hinges on a complex computer algorithm that calculates the most efficient aircraft routings and ride-sharing among passengers. Dayjet offers lower fares to passengers who are flexible in their departure and arrival times, thus allowing the computer to route airplanes more efficiently. A passenger flying from Naples, Florida, to Hilton Head, South Carolina, would pay about $1,800 for a nonstop flight departing at a specific time. But if he's willing to make the two-hour trip at a time of Dayjet's choosing (within a seven-hour window), the fare drops to less than $600. (Smaller windows have correspondingly higher fares.) He is guaranteed to arrive within his specified window, albeit with a likely stop somewhere and a fellow passenger aboard.

With long-term sights set on the United States' Northeast and West Coast, Dayjet has ordered 1,400 Eclipse 500s.

DAVID NOLAND

Brian Norris

AIRSHOW OPERATIONS COORDINATOR, TEAM ORACLE

COMMERCIAL PILOT AND AIRFRAME and powerplant mechanic Brian Norris manages travel, logistics, public relations, and aircraft maintenance for veteran airshow pilot Sean D. Tucker, who is sponsored by software giant Oracle. Though a college knee injury left Norris unable to fly for the military, he knew that airplanes would loom large in his career. He has worked with Tucker for 19 airshow seasons.

What do you carry in the Seneca support airplane?

All of our spare parts. A lot of those parts we've actually designed and built ourselves. Specialized tools and the regular wrenches and hammers. PR material. Hats. Autographed cards. Videotapes for TV stations. The headsets and the harnesses that photographers wear during photo flights. Poles for the ribbon cut. Luggage. Golf clubs. Sean's ice chest. Towels. Wax. Polish. My Seneca is a six-seat airplane, and we fly it with only two seats – the other four are removed. That airplane is filled from front to back. You couldn't fit a box the size of a loaf of bread in anywhere.

Before Team Oracle added a support aircraft to Sean Tucker's team, Brian Norris put 20,000 miles on his car each airshow season.

TYSON RININGER

Is fuel for Sean's biplane readily available at each airport where he flies?

The military bases don't always have avgas available. Usually they have jet fuel. But they will make an agreement with a local operator to bring fuel to the show. On rare occasions when the show [site] will not have avgas, they'll make a deal with an [off-site] operator to at least provide fuel. In those instances I'll fly my Seneca to [that] airport, fill it with 123 gallons, fly back to the base, drain the gas out with a little electric fuel pump, and put it in the biplane.

What's the best thing about your job?

I've been fortunate enough to lead photo flights with pretty much every civilian performer in the country. I've gotten to fly lead with the Thunderbirds following me. I've flown lead with the Blue Angels. That is a rewarding part of my job – to look over and see a big blue Navy jet sitting 10 feet off my wing. I used to watch the Blue Angels fly every year from the time I was five years old, and now they're following me around the sky.

Any advice for people who'd like to have a job like yours?

As corny as it might sound, follow your dream. You hear people say it, and a lot of people don't. I am living proof: Here I was working on computers, couldn't fly jets like I wanted to. Back then, nobody'd ever heard of Sean outside of California, and even the people who had were mostly competition pilots. I saw Sean fly, and I thought, *that guy's going places*. I started following him around. Fortunately, I was in a position where I could just work a few days a month and make enough money to get by on my computer stuff. I had every bit of faith that sooner or later some sponsor was going to give Sean what he needed to branch out.

Predators and Dragons

ALTHOUGH UNMANNED AERIAL vehicles are often touted as the future of air war, they've been around since 1917, when Ohio inventor Charles Kettering designed a flimsy unmanned biplane called the *Liberty Eagle*, better known as the Kettering *Bug*. Built on the cheap, the *Bug* was developed as a flying bomb, meant to carry explosives to targets 50 miles away. But the first world war ended before it could be used, and the *Bug* remained classified until World War II.

The first UAVs capable of *returning* after completing a mission were developed as the war in Vietnam began to escalate. That's when radio-controlled drones evolved into reconnaissance vehicles, explains Dik Daso, a curator in the aeronautics division at the National Air and Space Museum, which has recently opened an exhibit dedicated to the type of airplane whose pilot stays on the ground.

"The star of the show is the Predator," says Daso. "It was one of the first three airplanes that were authorized to deploy after [the terrorist attacks of] 9/11, and it might be one of the most significant combat airplanes we have in the collections" (see "Aircraft That Changed the World," p. 22). As significant as "Flak Bait," the Martin B-26B-25-MA that survived 207 combat sorties over Europe? That depends on how you define "significant," but the Museum's Predator was almost as busy. Built by General Atomics Aeronautical Systems, Inc., which sponsored the exhibit, the Predator flew nearly as many missions as "Flak Bait," with 196 combat sorties in Afghanistan.

The National Air and Space Museum's unmanned aerial vehicle exhibit features test aircraft as well as combat veterans. The black DarkStar (partially shown) hovers above the nose of the Predator (with gimbaled sensor) and the blue and white X-45A.

Advances in modern military UAVs have made it possible to strike an enemy from relative safety miles above the ground.

"The superstar weapon of Afghanistan and Iraq is a glider with an Austrian snowmobile engine, racing into combat at all of 70 miles per hour!" says James "Snake" Clark, director of Air Force Combat Support at the Pentagon and a former fighter pilot. "The Predator absolutely revolutionized warfare, and the one in the exhibition is the Elvis of Predators. It was the first rock-star Predator that we had. It was the first to deploy after 9/11, the first to test-fire a Hellfire missile, and the first to fire in combat in Afghanistan."

But have pilots always been so enamored with UAVs?

"Would I have given up my F-16 to go fly a drone? No. But, that being said, flying a Predator is a little more challenging," says Clark. "Once you put weapons on it, guys got really excited. Let's say you were a former -130 pilot, a C-17 pilot, and now you're

ERIC LONG (2)

shooting missiles at bad guys. Given a chance of an F-22 or an F-15, guys will always say they'd like to go to the real cockpit environment. But if you have to do a non-frontline flying job...the guys that are flying Predator are pretty happy. They know they're popping bad guys and saving good guys, and that's a lot of job satisfaction."

In addition to the Predator, the exhibition features the equally famous RQ-2A Pioneer, which the U.S. Navy used to great effect during the 1991 Gulf War. Crew members aboard the USS *Wisconsin* launched the Pioneer toward Kuwait's Faylaka Island to conduct bomb damage assessments after Iraqi defensive positions had been shelled. As the Pioneer swooped low over the island, a number of Iraqis waved makeshift white flags—the first soldiers to surrender in history to a UAV.

While the Navy has a long tradition of using remotely piloted helicopters, the Pioneer was its first fixed-wing UAV, and the aircraft was later used in contingency operations over Haiti and Somalia. Daso points out that the Pioneer's Navy roots are clear. "It *looks* sort of like a Navy ship," he says. "It's got the gray, glossy paint, and if you get a little closer, you'll see really big fasteners, really big rivets—they look just like the big bolts that hold the ships together."

Two other combat veterans are also on display: the AeroVironment RQ-14A Dragon Eye, used by the U.S. Marine Corps, and the RQ-7A Shadow 200, which flew with the U.S. Army's 4th Infantry Division, Stryker Brigade Combat Team number 2, and the 82nd Airborne Division.

Not all of the UAVs displayed at the Museum have seen battle; some are prototypes, such as Boeing's X-45A, the first UAV designed as a combat aircraft. David Abel, the crew chief on the test project, describes the two prototypes (the other is on display at Wright-Patterson Air Force Base in Ohio) and their abilities: "The two aircraft would take off in tandem, go out to the predetermined test area, and a target would pop up on the ground. The two airplanes would communicate with each other and determine which was in the better position, which had weapons on board for the mission, and which had the fuel required to complete the mission, and that one would peel off and attack the target. They did it time and time again, and they did it very accurately."

The best battlefield intelligence includes imagery from both UAVs and satellites, and the Lockheed Martin/Boeing RQ-3A DarkStar, designed with stealth in mind, was developed to linger undetected over enemy territory for hours at a time. "It's the spookiest one," says Daso of the saucer-shaped craft. The UAV never made it into production, however; after failures during flight testing, the Department of Defense terminated the program.

While the exhibit highlights the technological achievements of UAVs, Daso is quick to point out that the aircraft are only part of a complex system, and are incomplete without support personnel. "What's so great about this exhibit," he says, "is that you can educate kids and explain that you don't have to be a pilot to fly these things—or design them."

REBECCA MAKSEL

Visitor Information

Family Days Take a look at more than 50 visiting vintage, recreational, military, and homebuilt aircraft at Become a Pilot Day on June 14 at the Steven F. Udvar-Hazy Center in northern Virginia. Talk to pilots, test your piloting skills in flight simulators, and meet model airplane experts. Admission is free; parking is $12. The event runs from 10 a.m. to 3 p.m.

What's Up Receive regular updates on Museum events, read about artifacts, get detailed (and behind-the-scenes) exhibition information, and receive calendar listings by subscribing to the National Air and Space Museum's free monthly e-newsletter, *What's Up*. Sign up at *www.nasm.si.edu*.

Folklife Festival *NASA: Fifty Years and Beyond* showcases the role that the men and women of NASA have played in broadening the horizons of American science and culture, as well as the role that they continue to play. The Folklife Festival runs from June 25-29 and July 2-6, 2008 on the National Mall. The Festival is open daily from 11 a.m. to 5:30 p.m., and is free. Visit *www.folklife.si.edu* for more information.

ARTIFACTS

Welcome Discovery

USING ARTIFACTS AND TEACHING materials, National Air and Space volunteers explain to visitors the concepts of commercial aviation, space history, astronomy, planetary geology, and the invention of powered, human-controlled flight. Here, Jennifer Kelley, a Discovery Station volunteer, shows youngsters how the wrist connection on an Extra-vehicular Mobility Unit (or spacesuit) secures the gloves on space-walking astronauts.

"Hands Off" doesn't apply at the Museum's Discovery Stations, where budding pilots and astronauts get a feel for the artifacts.

DANE PENLAND

The Bridge that Did Not Fall

I REMEMBER MY ASSIGNED cold war mission very clearly. In July 1987, I was directed to lead a flight of four Fairchild A-10s to strike a bridge-overpass in the Thuringer Wald, a mountain range about 100 miles northeast of Frankfurt in what was then East Germany. The brick and concrete structure supported a train line that was expected to be used by units of the Soviet 8th Guards Army if Warsaw Pact forces invaded Europe. The train track passed over a key road; by destroying the structure, we could cut that track, and the resulting rubble would block the road below.

My plan was simple: Over the target, we would attack out of a circle, with each aircraft striking from a different direction, creating the most problems for those defending it.

My flight then went before a certification board. Our squadron commander said he was satisfied with our preparations. The senior NATO officer turned to an intelligence officer, who noted that we would likely destroy the target, but there was a good chance that two of our A-10s would be shot down. Enemy units in the area would defend it well.

We four pilots eyed one another uncomfortably. We all knew that once we were that deep in enemy territory, there would be no chance of rescue. If downed, our fate would be capture or death.

I had started my flying career as an Air Force pilot, graduating from flight training during the war in Southeast Asia. I subsequently served in the conflict as an OV-10 Bronco and O-1 Bird Dog forward air controller, then returned home to duty as a jet instructor. With the force reductions in the mid-1970s, I left active duty for an airline career, but continued flying with the Air Force Reserve. By the 1980s, I was flying A-10s, the anti-tank fighter-bombers, at a base just south of Kansas City, Missouri. I loved it. And at the height of the cold war, we had a real mission: Each summer, we deployed to Air Force bases in West Germany and served with active-duty units.

In 1987, we were at Sembach Airbase, southwest of Frankfurt, replacing a unit so it could return to England for a break from frontline duty. We assumed responsibility for alert missions; in the event of war, we had to be ready to launch aircraft on short notice to attack pre-selected targets in East Germany.

I could feel myself tense up. Certainly there was no reason to do so; everyone I encountered was friendly and helpful. But I still felt I was in enemy territory. What would we have seen from 500 feet or lower, traveling at 350 mph?

On that July day, when we learned that half of us might be shot down, we shuffled out of the briefing room and resumed our training flights. Preparing to return to our base in Missouri, we relinquished our assigned missions to the unit we had stood in for and headed home.

A few years later, the Soviet Union collapsed. With it went the Warsaw Pact and the threat that Western Europe might be invaded. Some deep thinkers said it was the resolve of NATO to defend itself that had prevented World War III.

In 1992, I was in Frankfurt on an airline trip and had a free day. On a stroll through Mainz, I went into a bookstore and picked up a map of Germany. Like all maps, it had been modified to remove the old border between West and East Germany. But I knew the terrain well, and, recognizing the train line and conjoining highway, I followed them to their junction at the bridge—my Thuringer Wald target. I found my old base at Sembach and retraced the path we would have flown from the base to the bridge.

I had to "fly" that mission.

I rented a car, and marked our route of flight on the map, using the circles, triangles, and squares with which we laid out a military mission. It was a short drive to my old base, which had been deactivated. I stared at the hardened aircraft shelters, large domed concrete structures. They could be destroyed only by a direct hit with a powerful bomb.

I drove northeast, passing south of Frankfurt, and stopped along what had been the border between the two Germanys. Walking along the remnants of the wall, I watched a team removing land mines. I also climbed into one of the guard towers that had been maintained by the East Germans and thought about what that tower represented.

I could feel myself tense up. Certainly there was no reason to do so; everyone I encountered was friendly and helpful. But I still felt I was in enemy territory. What would we have seen from 500 feet or lower, traveling at 350 mph? Part of the flight would have been across a wide valley. I

DARREL WHITCOMB

looked up at the ridges on each side and envisioned the anti-aircraft guns and missile sites the enemy would have set up there.

I drove into the hills that surrounded the target. Approaching a ridge, I remembered this would have been the point at which I would have split my flight for the attack. Then I rounded a turn, and there was the bridge—old, tired, and still in use.

I stopped the car and got out. As two stout horses pulling a hay wagon passed by, the farmer waved and shouted a greeting in German, which I returned in English. He gave me a surprised look and continued on. Hearing a train approaching, I walked up a path to the bridge. As the train passed, the ground rumbled slightly.

I laid out my map. There was higher terrain to the east, but the ridge fell off to the north. I could envision how we would have attacked from different directions. I could trace how we would have maneuvered our aircraft and where the bombs would have fallen. I could see them hit the bridge, and the bridge falling on the road below.

A bridge overpass in the bucolic East German countryside would have been the primary target for a flight of four Fairchild anti-tank A-10s on a 1987 cold war mission. The bridge still stands.

Over the years, I have visited many battlefields. This was a battlefield of a different sort: one from a war that had not been fought. Had World War III erupted, what would this relatively minor action have meant? It would have been, at best, a one-line entry in an operational report, noting that because a bridge had been dropped, the advance of the Soviet 8th Guards Army in one sector had been slightly delayed. Then again, most all wars are accumulations of countless minor actions.

I tried to recall the other three pilots in my flight, then realized I had strayed into a gray area. As a historian, I could deal with the bridge. But by recalling those pilots, I was personalizing the mission. Now when I looked up and saw the circling A-10s, there were men in them, with names and faces and families.

I could see the enemy anti-aircraft guns and missile sites on the high ground. I could see crews firing long bursts of deadly rounds. I could hear the *whooosh* of the missiles as they streaked skyward with their warheads, seeking our maneuvering aircraft.

We would have made desperate warning calls to one another. The airplanes would have shuddered as the shells and missiles found their marks. In terms of a world war, this bridge was a minor matter. But to us, the men assigned to destroy it, the mission could have been the final event of our lives.

Back home a week later, I went down to the basement and pulled out my box of old military stuff. I opened up the unit history and looked at a photograph of the four of us in my flight. Then I opened my logbook and found the entries for the summer of 1987. I remembered the gunnery flights to the ranges at Grafenwehr, Hohenfels, and Wildflecken, and the navigational flights through Bavaria. But there was no logged mission to the bridge.

And that was the point. The bridge itself would not have been worth any of our lives. But the resolve that the mission represented—that I saw in our young faces in our unit history photos—was where the value lay. I have to agree with those deep thinkers: In being prepared to fly that mission, we prevented it from having to be carried out. And that resolve, magnified by the efforts of so many throughout the NATO alliance, prevented the conflagration that would have been World War III.

DARREL WHITCOMB

The El Toro Follies

That Cessna (circled) isn't there. Since no one was around to take a picture of his "fly-out," the author digitally inserted the airplane in his overhead shot of a deserted El Toro.

MICHAEL CHURCH

EL TORO IS A Marine Corps Air Station near Irvine, California, with a fabled history—think Helldivers, Wildcats, Phantoms, and Hornets. Created in 1942 out of World War II pressures to train pilots for the South Pacific, the base uprooted the largest lima bean field in North America. The first pilot to use the facility was a Major Carmichael, who made an emergency landing while the base was still under construction. I have the honor to have been the last pilot of a fixed-wing aircraft to take off from Marine Corps Air Station El Toro. My ride was more tame: a Cessna 152, and in 2007 the base had a decidedly ragtag appearance.

After the war, El Toro grew into the West Coast's center of Marine aviation. The base was closed in 1999 and, after years of wrangling over its future, now sits idle, awaiting conversion to a "Great Park" of residences, golf courses, schools, and parkland. Its only tenants are security personnel, parked RVs, and an enterprise that photographs expensive foreign cars.

Although I never flew for any branch of the military, I have a connection to the base. For 15 years, our flight school, Sunrise Aviation, ferried aircraft seven miles from Orange County Airport to participate in the annual Marine Corps airshow at El Toro. Some 400,000 attendees showed up each day to bask in the sun and take in the sights and sounds of a major military spectacle.

The Marines were gracious hosts. On our school's first visit, our Pitts Special attempted to taxi across the heavy arresting cable used for carrier landing practice. The tailwheel assembly hung up on the cable and the pilot sat helpless on the runway until several Marines in camouflage ran over to lift the airplane clear. I was concerned their enthusiasm might inadvertently cause damage—they're used to wrestling with heavier and sturdier machines—but the rescue went smoothly.

On another occasion, we watched as a Navy F-14 pilot arrived late for the static display line and pivoted neatly to position his jet into its parking spot. In the turn, the jet blast caught a line of 10 blue Porta-Potties and tipped them over, occupants and all. In response to a chorus of outraged shouts, camouflaged Marines again sprang to the rescue.

One year a semi-trailer filled with beer was left parked on the shoulder of a taxiway. As the paving softened in the sun, the trailer began to list. The situation developed beyond even the Marines' resources: As majestic as the *Titanic*, the trailer slowly succumbed and rolled over, refrigeration unit still pumping, gallons of suds leaking into the California scrub.

El Toro even had a role in the 1996 movie *Independence Day*, as the base from which F/A-18 pilot Steve Hiller (Will Smith) departs to bag an alien ("Who's the man? Huh? WHO'S the man?") and also served as the point of departure for the flying-wing bomber that nuked the invading Martians in 1953's *War of the Worlds*.

Memories like these made me chuckle as I taxied the little Cessna over concrete seams sprouting weeds. Two days earlier, an instructor had made an emergency landing on the base, and we had just persuaded the city government to let us take off from the field after we repaired the airplane. It had been an uphill battle: The city would not grant permission without the Federal Aviation Administration's blessing, and the FAA wanted nothing to do with any of it ("That's not an airport, and it's not our job!") and recommended the city make us crate up the airplane and truck it out. Only after I suggested that chore might require months did the city acknowledge that El Toro might be an airport after all, if only for 15 minutes.

I maneuvered through a maze of traffic cones laid out by the car-picture folks and eventually found a runway marked with Xs that signaled "no landings allowed." Within 20 seconds I secured my place in El Toro's history.

MICHAEL CHURCH

ANYTHING'S POSSIBLE

TORGOEN
SWISS

PROFESSIONAL PILOT WATCHES

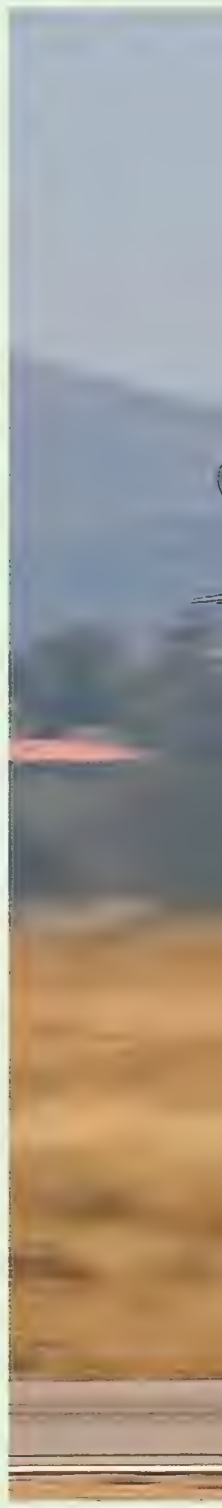
Quartz Precison Swiss Movement
Sapphire Scratch Resistant Crystal
Surgical Grade Solid Stainless Steel

Available at fine jewelry stores

www.torgoen.com

AIRCRAFT THAT CHANGED THE WORLD

THE EDITORS FEARLESSLY (OR FOOLISHLY) PICK 10.



ANTHONY ZELJEZNJAK

WORLD CHANGERS. It's almost easier to explain what we don't mean by that phrase than to define what we do. We have not compiled a list of trailblazers, like the de Havilland Comet, the world's first jetliner. Nor is this a list of airplanes that represent the greatest advances of aeronautics, such as the experimental aircraft that led to supersonic flight. Rather, we looked for craft that had an impact beyond the realm of things that fly, that reached into the larger culture and touched even those who aren't frequent fliers or connected to aviation.

Published by Boston Mills Press, 2007

Some of our choices are individual airplanes that happened to play a critical role in a world-changing event; others are aircraft types that were so significant in commerce or in war that we could truly say of them: "These changed history."

We were inspired by the recent book *50 Aircraft That Changed the World*, and we could see immediately that authors Ron Dick and Dan Patterson had followed a wiser course: They had picked 50. We could accommodate only 10. We ended up with a list that includes some of those in the book, plus a few of our own.

The most heated debate that broke out in the course of making our selection was also the most revealing; it showed how stringent our standards were—and how subjective. It was over *The Spirit of St. Louis*. Some editors argued that of course we had to include the airplane flown on the first solo, nonstop trip across the Atlantic Ocean—a trip that made its pilot an international celebrity and inspired a generation to fly long distances, or at least dream about it. Months after the 1927 event, when Charles Lindbergh flew the airplane, a purpose-built Ryan, on a tour across the United States to promote aeronautics, an estimated 50 million people—42 percent of the nation—turned out to see it.

CHANGED

But was it the airplane that people found so inspiring, or the pilot? It's hard to imagine that journey being completed by anyone other than Lindbergh, but not so difficult to think that he could have done it in another type of airplane. In fact, he had considered an alternative, the Wright Bellanca WB 2.

We're sure there are readers (more than a few in St. Louis and in San Diego, where *The Spirit* was built) who will disagree with that reasoning, or with other choices we made. In the end, selecting 10 aircraft from so many possibilities simply became a good excuse to do one of our favorite things: talk about airplanes. We bet you'll want to join the discussion.

—The editors

This MiG-15, a trainer bought by retired California contractor Tom Smith, has performed at U.S. airshows, demonstrating that jet fighters need not be pointy to impress. Since 1949, the Soviet Union and other nations have cranked out more than 18,000 examples of this internationally popular classic.

1. Wright 1905

WE KNEW WE WANTED to start with a Wright airplane, but which most deserved the title of world changer? Wright biographer Tom Crouch, a National Air and Space Museum curator of early flight, nominated the brothers' third powered aircraft. "The 1905 was the world's first practical airplane," he observes.

"The best of the four flights made by the 1903 aircraft at Kitty Hawk, North Carolina, on December 17, 1903, was only 852 feet in 59 seconds," Crouch continues. "With that marginal success in hand, the Wrights decided to transfer flight operations to Huffman Prairie, eight miles east of their hometown, Dayton, Ohio. They built and tested two aircraft there, one during 1904 and another in 1905.

"Over the course of those two seasons, the Wrights fine-tuned their design, stretching the aircraft to improve stability and control, enlarging the control surfaces, and improving the propellers. (The same engine, a virtual replica of the one that powered the 1903 aircraft, powered both the 1904 and 1905 models.) On October 5, 1905, Wilbur Wright flew a distance of 24.5 miles in 59 minutes, 23.8 seconds. The brothers had finally achieved their original dream: developing a practical airplane capable of remaining aloft for a significant time and maneuvering under the full control of the pilot.

"The Wrights then faced the task of selling their invention. By the spring of 1908 they had been granted a patent and had signed contracts to sell airplanes to both the U.S. Army and a French syndicate.

"The brothers had not left the ground since the October 5, 1905 flight, however. In addition to brushing up on their flying skills, they had to make their first flights with a passenger, something required by both contracts, and operate a new set of controls necessitated by upright seating, another stipulation of the contracts.

"They pulled the 1905 machine out of storage and modified it with two upright seats and the new control system. They shipped it back to the Kill Devil Hills of North Carolina because they wanted to undertake the test flights in an area with steady winds, soft sand, and isolation from prying eyes. On May 14, 1908, first Wilbur and then Orville took their mechanic, Charles Furnas, up for a ride. These were the first airplane passenger flights in history."

Crouch's Museum colleague, early-flight curator and Wright scholar Peter Jakab, concurs with this choice of aircraft: "Even the Wrights did not see the 1903 airplane as the conclusion of their experimental work," he says. "They had identified the final goal as a 'machine of practical utility.' They understood that the 1903 airplane, although embodying all the key technology, was not quite that. When they could stay aloft for an extended period, under the sure command of the pilot, and consistently land safely, they knew they had that 'machine of practical utility.' The 1905 machine was that airplane.

"When the Wrights were regularly flying over Huffman Prairie in the fall of 1905," says Jakab, "that's when the world truly changed."

LIBRARY OF CONGRESS

DAN PATTERSON

The 1905 (left) was the first aircraft flyable for long stretches. Below: A modern replica, in which builder Mark Dusenberry retraced a 1905 Wright flight.

NASM (SI 73-5887)

"THE F13 WAS ESSENTIALLY THE FIRST aircraft to anticipate the onset of 'modern' air transport: cantilever [no wing struts], all metal, low wing, monoplane, streamlined (by the standards of the day)," says aviation historian Dick Hallion, this year's A. Verville Fellow at the National Air and Space Museum. The metal construction, adds NASM air transport curator Ron Davies, "made it sturdier and less vulnerable to damage than the wood-and-fabric biplanes of its competitors. The metal was especially critical in resisting heat and humidity in tropical countries."

The F13 first flew in 1919 (as the J13), and by the end of the year was in commercial service in Germany. "It established [founder Hugo] Junkers in a position of global air transport dominance that his firm would not relinquish until the mid-1930s,

3. Boeing 314

IN THE HANDS OF Pan American Airways, Boeing's majestic flying boat, the 314, established mail and passenger routes across the north Atlantic, south Atlantic, and Pacific. In *Pan Am, An Airline and Its Aircraft*, NASM's Ron Davies writes: "The B 314 flying boat put up all kinds of records, but none could compare with the establishment of the North Atlantic service in 1939 in the epoch-making series of inaugural flights which were, perhaps, Pan American's greatest contribution to air transport in all its distinguished history."

On the 314's Pacific route (San Francisco-Honolulu-Midway Island-Wake Island-Guam-Manila), service was opulent—even the flight deck was described as luxurious—with a lounge, dining area, sleeping berths, and dressing rooms, as well as chefs and china from four-star hotels. Advertisements for the Clippers (named for their nautical forebears) promised an experience that was not just safe but sumptuous, exciting the public about flight.

The 314s were the stars of Pan Am's fleet for only three years; World War II shut down commercial operations. Still, it was not until the 1960s, with the de-

The *Honolulu Clipper* was essentially the prototype 314. Though it took up to 20 hours to get from San Francisco to Honolulu, passengers were treated royally, and the public warmed to flight.

but of wide-body airliners such as the Boeing 747, that the B-314s were dethroned as the world's largest scheduled-use commercial aircraft.

2. Junkers F13

to Donald Douglas," says Hallion. The F13 was used in the first airline service in the Americas (Colombia's SCADTA).

Says Davies, "Unlike postwar transport airplanes that were modified from military types, the F13 was designed to carry passengers in an enclosed cabin. The four cushioned seats had seat belts, and the cabin was lighted and had picture windows." Now *that's* air travel.

After World War I, Germany was prohibited from operating the aircraft, but it sold them or licensed manufacture to 30 countries, including Hungary, Iceland, the Soviet Union, and Japan. In those years, the F13 established air routes in both Europe and the Americas. The last retired in 1948.

Behold, the first incarnation of the airplane as we know it today. Surprisingly snazzy for its time, the F13 was one giant step beyond wood, fabric, and struts.

COURTESY DEUTSCHES MUSEUM

ERIC LONG AND MARK AVINO (SI 98-15873)

4. The *Enola Gay*

IT WAS THE FIRST use of an atomic bomb: On August 6, 1945, the B-29 Superfortress *Enola Gay* bombed the Japanese city of Hiroshima, killing 70,000 and hastening the end of World War II. (When another Superfortress, *Bock's Car*, dropped a second atomic bomb three days later on Nagasaki, Japan surrendered.) The two missions averted a planned U.S. invasion in which casualties were projected to run into the millions.

The image of those mushroom clouds was unforgettable. For the next 50 years, the nightmare scenario of another attack of such magnitude kept the two nuclear superpowers locked in a tense and costly cold war.

The B-29 was the world's first nuclear-capable aircraft. It also was the first with a pressurized compartment for the flight crew and the first U.S. bomber with an integrated radar to supplement its Norden bombsight. With a maximum takeoff weight of 140,000 pounds, the four-engine, 11-crewman B-29 could carry up to 20,000 pounds of bombs. It was flown from 1943 to 1954, although the Air Force continued flying variants as tankers until 1978.

Late in World War II, three B-29s made emergency landings (a fourth crash-landed) in Vladivostok, Siberia, after bombing runs over Japan. The Soviets kept them, studied them, and copied them, producing the Tu-4 bomber. Until about 1955, the Tu-4 was the main bomber of the Soviet Union—America's cold war enemy.

NASM (SI 2000-4554)

After the historic bombing of Hiroshima, the *Enola Gay* landed on Tinian, in the Mariana Islands (right). Today, the aircraft has been restored (above: cockpit) and is displayed at NASM's Steven F. Udvar-Hazy Center.

WHILE THE HELICOPTER – with its enviable ability to hover, dart in all directions, and land virtually anywhere—had achieved a measure of success in the 1930s and 1940s, it wasn't until the Sikorsky S-55 made its debut with the U.S. Navy in Korea in 1950 that rotary-wing history was utterly transformed. "For my money," says Roger Connor, NASM's vertical flight curator, "though other models pioneered various military and civil applications, the S-55 was the one that saw a real return on the investment put into helicopter development."

The dazzling success of the S-55—both nationally and internationally—was based on the aircraft's ability to fill multiple roles: troop and cargo transport, air assault, and casualty evacuation. That versatility resulted in unprecedented demand—1,700-plus were built, more than any previous helicopter type.

The design was brilliant: Sikorsky Aircraft completely reconfigured its earlier layouts to create the first helicopter with a cabin capable of carrying 10 passengers or seven stretchers, and

5. Mikoyan-Gurevich MiG-15

STILL A HOT-LOOKING airplane 59 years after it entered service, the Mikoyan-Gurevich MiG-15 made its mark during the Korean War as the Soviet Union's first jet-powered day interceptor with a pressurized cabin and an ejection seat.

The MiG-15's mission was to pick off U.S. B-29 bombers, which led to storied dogfights between the MiGs and the B-29s' fighter escorts, North American F-86s. Though an improved version of the MiG-15 could climb higher and faster than the F-86, U.S. Air Force pilots generally made up the difference with better aerial combat training. Still, the 670-mph MiG-15 put the world on notice that the Soviets could build cutting-edge aeronautical technology.

"The MiG-15 gave the Soviet air arm legitimacy and lethal potential in the early years of the cold war," says Von Hardesty, NASM's curator of Russian aviation history. "The MiG-15 also possessed a certain aesthetic quality: sleek, fast—the very embodiment of what a jet fighter should be."

Its performance must have reinforced that impression. More MiG-15s—12,000—have been made than any other jet aircraft in history. (Counting licensed versions made in other countries, the number reaches 18,000.) The type has been sold to 43 countries—from Sri Lanka to Cuba to Uganda.

A row of MiG-15s outside an underground air force complex in Kucove, Albania – one of more than 40 countries that have armed themselves with the long-lived fighter.

CHRIS LOFTING

6. Sikorsky S-55

moved the engine to the nose, enabling easier maintenance and solving the center-of-gravity problems previous single-rotor models had experienced. By the end of the Korean War, Sikorsky's machine had rescued downed pilots, saved the lives of 10,000 wounded soldiers, and delivered escaped prisoners from behind enemy lines.

In addition, the S-55 served as the core of counter-insurgency efforts by the British in Malaya and the French in Indochina, pushing both nations to establish their own aggressive helicopter programs. In American and foreign civil service, the S-55 pioneered helicopter airline transport.

Says Connor, "The accomplishments of the S-55 shifted public opinion—as well as the opinion of military and aviation insiders—from seeing the helicopter as an amusing but not terribly practical curiosity to a necessary tool of the modern age."

The S-55 wasn't pretty, but its many capabilities moved vertical flight forward.

NASM (SI 90-12967)

BONNIE KRATZ

7. Cessna 172

CESSNA'S FOUR-SEAT, high-wing classic is the fresh-faced girl next door: no knockout but a great personality. In 2006, on the occasion of the 172's 50th birthday, *Air & Space/Smithsonian* researcher Roger A. Mola wrote, "There's hardly a pilot flying today who hasn't logged at least a few hours in a Cessna 172 Skyhawk." It's the most successful mass-produced light aircraft ever, with some 36,000 built and still counting, recalling those McDonald's signs boasting "Billions and Billions Served."

One flight made the ubiquitous little airplane a world changer. In 1987, Mathias Rust, a young West German, rented a 172 from his flying club and flew it to the Soviet Union, setting down in Red Square in the heart of Moscow, a gesture he called building an "imaginary bridge" ("The Notorious Flight of Mathias Rust," June/July 2005). Rust reasoned that if he could get through the Iron Curtain without being intercepted, "it would show that [Soviet leader Mikhail] Gorbachev was serious about new relations with the West." Author Tom LeCompte noted that "Rust's flight damaged the reputation of the vast Soviet military and enabled Gorbachev to remove the staunchest opponents to his reforms." Soviet citizens had been told that if they let their military guard down for an instant, the West would annihilate them. "Rust's flight," observed LeCompte, "proved otherwise."

Last year, Cessna announced it will build a 172 Skyhawk TD, for "Turbo Diesel," that will burn Jet A fuel.

The Cessna 172 has been around so long, the variant list is up to the letter "S." Below: A Spanish flying club's N. Next year: A turbo-diesel version. (Is rocket power next?)

OSCAR LABORDA SANCHEZ – IBERIAN SPOTTERS

8. Learjet 23

"THERE WERE 'bizjets' that preceded the Learjet," says *Air & Space* founding editor George C. Larson, "but Bill Lear's idea for a smaller and simpler—but fast—aircraft really popularized the idea that businessmen ought to travel based on their own schedules, rather than the airlines'."

At Miami's Opa Locka airport in 1964, spectators get their first look at the then-new (and still sexy) Learjet 23.

The idea of jets dedicated to business travel first found incarnation in the early 1960s, with the introduction of the Lockheed JetStar and North American Sabreliner. Both were spinoffs of military jets. The Learjet likewise evolved from a fighter: the Swiss P16, which never made it into production.

Says Larson, now a senior editor at *Business & Commercial Aviation*: "The first Learjet was called the model 23 because it was certificated under Federal Aviation Regulations Part 23, for airplanes less than 12,500 pounds, and that made it easier to get through the Federal Aviation Agency's approval process. Part 25, for heavier aircraft, was way harder. What was wonderful about the Part 23 thing is that the airplane was certificated with a max gross weight of 12,499 pounds. Oh, that Bill Lear."

The Learjet 23 carried a crew of two and up to seven passengers. It had a range of 1,800 miles and cruised at 485 mph.

Larson notes that the jet succeeded in part because "the company sold the airplanes very effectively, offering to 'recourse,' or buy back, an airplane if things weren't working out for the company that bought it. That brought a lot of individual entrepreneurs and people like [celebrity lawyer] F. Lee Bailey on board."

The first production 23 was delivered in October 1964. Cost: $550,000. Says transportation writer John W. Smith: "A whole new class of aircraft had been created: the personal jet."

FIND OUT MORE
www.airspacemag.com

THE AIRCRAFT THAT CHANGED AVIATION: A noted historian tells us his choices.

9. Boeing 747

SO MAGNIFICENT a technological achievement was the Boeing 747 airliner that cultural historians have called it the 20th century's cathedral. Nearly 40 years after its first flight, it remains, along with the photograph of Buzz Aldrin standing on the moon, the most recognizable symbol of U.S. engineering brilliance. When it was introduced, airports the world over reinforced runways and made other infrastructure changes to receive it.

Still, it is not grandeur or technology or even impact on infrastructure that qualifies it for a place on this list. It was, after all, an evolutionary design. Its creators—Boeing president Bill Allen and Pan American Airways legend Juan Trippe—believed it was merely an interim answer to the demand that airlines would eventually meet with a revolutionary supersonic transport. The SST, they predicted, would relegate the 747 to hauling cargo.

But as wise as those two were, they could not see the future. And what qualifies the Boeing 747 as a world changer is that since it entered service in 1970, 96 carriers around the world have used the wide-bodies to fly 3.5 million people to their destinations. Consider the impact of all of those trips: the business deals made or altered, the information exchanged, the exposures to other cultures, the families and friends reunited.

WOLODYMIR NELOWKIN

The 747's first Australian landing: Basking grandly in the attention at Sydney's international airport in 1970.

DAVID S. CHULMAN

10. General Atomics MQ-1 Predator

IN NOVEMBER 2002, A VEHICLE traveling in Yemen and believed to be carrying terrorists was destroyed by a Hellfire missile. What makes the kill historic is that it was executed by a flying robot. The first unmanned aerial vehicle to kill human beings, the MQ-1 Predator has changed the rules of warfare.

Built by General Atomics Aeronautical Systems, the Predator has been operational in Bosnia since 1995 and now is flying missions in Afghanistan and Iraq. The Air Force deployed the latest version, the MQ-9 Reaper, to Afghanistan last October.

The Predator, which has an operational ceiling of 50,000 feet, is flown remotely by a "pilot" and two sensor operators housed in a trailer on the ground. The UAV has a nose camera, variable-aperture TV and infrared cameras, and a synthetic aperture radar to see through smoke, clouds, or haze. The RQ (R for "reconnaissance," Q for "unmanned") model flies long-endurance, medium-altitude surveillance missions, while the MQ ("multi-role") version can carry up to four Hellfire II anti-armor missiles, two laser-guided bombs, and a 500-pound, GPS-guided Joint Direct Attack Munition precision bomb.

Today, the United States and other countries are increasing their use of UAVs for civilian missions, such as law enforcement, border control, and ocean surveillance. Even Hollywood has discovered their potential, putting them to work as movie camera platforms. Here's an aircraft that has changed not just the real world but the world of fantasy as well.

STAFF SGT. SUZANNE M. JENKINS/USAF

No pilot, multiple roles: The MQ-1 provides firepower, surveillance, and recon.

Detect

& Direct

THE NAVY'S NEWEST HAWKEYE GETS CLOSER TO THE FIGHT.

BY PRESTON LERNER » PHOTOGRAPHS BY CHAD SLATTERY

COMMANDER HERB CARMEN is the executive officer of VAW-116, a U.S. Navy squadron that flies four E-2 Hawkeyes. But at the moment, 15 seconds from a carrier landing training exercise at Point Mugu Naval Air Station, Carmen looks less like a pilot on final than a circus performer juggling swords and chainsaws—feet dancing on the rudder pedals, eyes darting between instruments and environment, left hand working the yoke while the right gooses the throttle as the airplane lurches through turbulent skies off the California coast.

E-2s, the electronic eyes of the fleet, have been in production longer than any military airplane in U.S. history. That is the great irony of the Hawkeye. Although the airframe first flew almost 50 years ago, the E-2C plays a uniquely pivotal role in the fighting doctrine of today's modern military. Yes, it was conceived as an airborne early-warning aircraft to keep the fleet safe while steaming in unfriendly waters. But its powerful array of radars and communications devices makes it a perfect weapon for modern network-centric warfare, and it's turned out to be almost as useful for ground operations—and for foreign air forces—as it is for its original purpose.

In service since 1964, the E-2 Hawkeye first flew missions that warned Navy vessels of threats. The C model (denoted by the plus symbol on the nose) still watches over the fleet, but now coordinates air-to-ground attacks in hot spots around the world.

"We're like the guys who climb up on top of a hill and see what's going on down below," says Randy Blackmon, the commanding officer of VAW-116. "We've got a God's-eye view of everything that's happening. So as the E-2 goes, so goes the mission. We've seen that again and again, and not just during training. At the start of Operation Iraqi Freedom, a lot of guys were bringing bombs back to the boat [after failing to find targets during combat sorties]. Then E-2s started getting into the party, and they started putting two and two together, hooking up people with targets."

Carmen's E-2C Hawkeye 2000 lands at a relatively sedate 140 mph, so the pucker factor doesn't rise to F/A-18 levels. But unlike the Hornet, the Hawkeye isn't equipped with digital flight controls, so it has to be flown by a pilot rather than a computer. Further complicating matters, it's the biggest bird in the carrier air wing, with a wingspan that permits only four feet of deviation from the centerline of the carrier's flight deck. Also, to minimize the parts inventory, both of the Hawkeye's propellers spin in the same direction, so whenever power is adjusted, the airplane yaws. And, thanks in part to the droopy four-tip tail section (a product of an aircraft carrier's height restrictions and aerodynamic anomalies caused by a 24-foot-wide rotating radar dome that sits like a mushroom atop the fuselage), pitch is super-sensitive to throttle inputs. So every carrier landing is something of a spectacle.

With the E-2 sinking at a rate of 500 feet per minute as it approaches the simulated carrier deck (actually Point Mugu's Runway 27), Lieutenant Mike Vogel, manning the radar scopes in the back of the airplane, warns me over the radio: "This isn't an airliner. My advice is to clench your teeth when we land so you don't bite your tongue." Carrier landings don't allow for niceties such as flaring before touchdown, so the Hawkeye slams down, successfully "trapping" an imaginary three wire. (Aircraft carriers have four arresting wires, but the three wire is the one pilots try to catch with their tailhooks.) Carmen applies full power, then eases back on the yoke, and the airplane effortlessly wings out over the Pacific for another touch-and-go.

"It's pretty peppy for a prop plane," says Carmen. He's got 2,400 hours in Hawkeyes, so it's understandable that he trumpets their performance. "I know it's not the sexiest aircraft on the flight deck. But the guys who carry weapons and drop bombs couldn't do what they do without us. The E-2 is like the quarterback of the fleet. The Hornets and Prowlers are the wide receivers and the running backs. They're the ones who score the touchdowns. But if the quarterback doesn't perform well, they don't perform well either."

An E-2's pilot and copilot earn their pay, especially during night carrier landings. But the heavy lifting in a Hawkeye is done by the three naval flight officers, known colloquially as tube monkeys, who man a trio of 21-inch computer screens in the back end of the airplane. While an E-2C loiters at high altitude, they use their radar to monitor what's going on in the entire theater and to zoom in on specific areas. But in addition, their extensive communications systems—conventional radios, satellite units, data-links, even text-messaging—allow them to stay in touch with all relevant units on land and sea, in the air, and under water. Not for nothing is the senior naval flight officer called the "mission commander"; he might well know more about the battlefield situation than anybody in the fight.

"The E-2 is in many ways the centerpiece of modern carrier aviation," says Commander Richard Weathers. Now head of the Navy's E-2C weapons school, Weathers was the executive officer of VAW-115 during the invasion of Iraq in 2003, when he and his commanding officer convinced the air wing commander to send Hawkeyes over land to coordinate ground-support and interdiction missions. "Once we were able to get close enough to the fight, our strike aircraft started coming back 'clean wing'—without any bombs," says Weathers. "Today, I believe, any strike group commander would consider it unthinkable to go into battle without an E-2."

The Hawkeye's 24-foot rotating radar dome (above) can cover six million cubic miles, enabling an E-2's three naval flight officers (below) to monitor an entire combat theater.

ONE OF THE GREATEST limitations of radar is that it operates by line of sight. The most obvious solution is to elevate the radar above the curvature of the earth. Hence the development of airborne early-warning aircraft, starting in World War II with a Grumman Avenger torpedo bomber retrofitted with radar to protect Navy ships from kamikaze attacks.

The E-2 first flew in 1960, joining the Navy fleet in 1964. The Hawkeye is dwarfed by the U.S. Air Force's Boeing E-3 Sentry airborne warning and control system air-

The Maestro

THE ADVANCED D MODEL (denoted by the delta symbol on the nose) will begin replacing E-2Cs in 2013. E-2Ds will have the classic Hawkeye airframe but their radar will have a longer range. The D will be an all-seeing, all-knowing information powerhouse, able to communicate directly with (clockwise from top) communications satellites; unmanned reconnaissance aircraft, such as Northrop Grumman's carrier-capable X-47B; submarines; search-and-rescue craft, such as Sikorsky's MH-60; aircraft carriers; unmanned scout aircraft, such as Northrop Grumman's MQ-8B Fire Scout helicopter; ground forces and command centers; and piloted attack aircraft, such as Boeing's F/A-18E/F Super Hornet.

JIM VECCIA/NORTHROP GRUMMAN

craft, which performs a similar function, albeit with a much larger crew. Because the E-2 has to fit on an aircraft carrier, the Hawkeye's wingspan tops out at 80 feet, 7 inches. Over the years, E-2s have been fitted with several generations of T56 turboprop engines, originally built by Allison and now by Rolls-Royce. The Hawkeye 2000 is equipped with a pair of T56-A-427 engines rated at 5,100 shaft horsepower apiece.

Until recently, the E-2's engines sported wicked four-blade props, which generated a hellacious racket (imagine an unmuffled Harley-Davidson running through a stack of Marshall amps). The noise (and destructive power) of the props made the E-2 a fearsome presence on the flight deck and inspired the nickname "the Hummer." Now fitted with fuel-efficient eight-blade props that are gentler on E-2 airframes, the airplane sounds more like a giant swarm of super-sized bees. "Not only is the eight-blade propeller quieter, but it's also a lot smoother," says Lieutenant Jon Gathman, a VAW-116 naval flight officer. "When you came back from a four-and-a-half-hour mission with the four-blade, you used to be exhausted from all the vibration it had put on you."

The E-2C's claw-like eight-blade propellers are more fuel-efficient – and quieter – than the noisy four-blade props that preceded them. The Hawkeye's carrier mate, the C-2A Greyhound cargo aircraft, will transition to eight-blade props later this year.

JAROD HODGE/US NAVY

Hawkeyes have no digital flight controls, so every landing is a stick-and-rudder affair, with pilots working hard to keep the ungainly aircraft on course.

Although the fundamental airplane hasn't changed for nearly half a century, the E-2 has gone through a long and complicated series of model changes driven by electronic upgrades, most notably to the radar. Even in the unlikely event that you miss the huge rotating radar dome, you'd recognize the E-2's *raison d'être* the instant you climbed inside. The belly of the starboard fuselage is crammed with radar gear. Snaking through riveted boxes are tubes of the exotic vapor-cycle cooling system required to keep the electronic units at safe temperatures. The cooling system is so important that monitoring it is a primary flight responsibility of the radar operator, the most junior of the Hawkeye's three naval flight officers.

© 2008 SARAH WHORTON

"We're just a big equipment van," jokes Lieutenant Commander Carl Whorton of the E-2's electronics-filled cabin.

Walk (hunched over) back past the radar gear and you reach the "office" of the Hawkeye, a cramped space bristling with buttons, switches, gauges, and computer screens. Here the three naval flight officers sit line astern for takeoff, then swivel their seats 90 degrees to the left to face their radar scopes and communications displays. The high-power UHF Doppler radar is able to monitor six million cubic miles and track 20,000 targets simultaneously, keeping its operators tolerably busy.

Although the pressurized cabin is a mask-free environment, the naval flight officers continue to wear their bulky flight gear and remain strapped to the heavy parachutes that are integrated into their seats. Fortunately, their workstations feature metal trays that slide out to expose keyboards and built-in trackballs. The close quarters also allow the naval flight officers to pass notes, communicate by hand signals, and, when things get crazy, even operate each other's equipment. "We get so much information coming through our scopes and the radios that it's easy to lose track of what the airplane itself is doing," says Lieutenant Commander Carl Whorton, who saw action over Afghanistan.

Case in point: During the push toward Baghdad, Carmen was flying an E-2 in a night mission over Iraq when he saw a shower of sparks rush past the cockpit: an Iraqi missile. He banked violently to the left and went to full power. A naval flight officer in the back end got on the radio, supremely annoyed and wondering what the hell was going on.

"When we told them that we'd gotten shot at, he didn't believe us, and he said something like, 'Yeah, right,' " says Carmen. Only after much heavy breathing and expletives undeleted was the truth accepted. Says Carmen: "Even as we were flying that night, I remembered a Churchill quote: 'Nothing in life is so exhilarating as to be shot at without result.' "

Every carrier air wing includes a four-Hawkeye squadron. Typically, an E-2 is the first airplane to launch and the last to land. For a classic airborne early-warning mission, it takes up station high above the fleet. The mission commander, known as the CICO, or combat information center officer, is the naval flight officer sitting in the middle seat. His radar scans 300-plus miles to identify threats, and he's in radio contact with the air defense commander, usually stationed on an Aegis missile cruiser. If he gets a radar hit that isn't squawking (sending out aircraft-identification signals from an onboard transponder), the E-2's air control officer, who sits in the back seat, zooms in on the inbound track and radios the Hornets doing combat air patrol duty.

Prey to corrosion and metal fatigue like most carrier-based aircraft, the Hawkeye is high-maintenance. Powerplant specialist Zamir Alvarez (at left) and structural mechanic Joe Brandt work over an E-2 assigned to VAW-123.

Commander Herb Carmen (center), an E-2 pilot and executive officer of VAW-116, and his flight crew – (left to right) copilot Lieutenant Commander Anthony Ramirez and naval flight officers Lieutenant Casey Aandahl, Lieutenant Jon Gathman, and Lieutenant James Stevens – are based at Point Mugu Naval Air Station in California.

Because the E-2 was originally designed for seagoing missions, its radar has trouble filtering out clutter on land and objects skimming over the ground, such as cruise missiles and helicopters. To enhance the Hawkeye's flexibility, Northrop Grumman is developing an E-2D, with an APY-9 radar system that dramatically improves clutter rejection while expanding search volume by 250 percent. Also, unlike the current antenna, which scans 360 degrees every 10 seconds, the new one can pause to lock onto targets, which will provide the radar operators with even more information to digest. To spread the workload, the new design gives the copilot a scope of his own so he can participate in the E-2's tactical mission when he's not helping fly the airplane.

MILOSZ RETERSKI/US NAVY

"We're no longer a blue-water battlegroup Navy," says Captain Randy Mahr, the E-2 program manager. "We're now a Navy that operates much closer to land, so we've expanded the E-2's mission and designed it to be supportable through the middle of the 21st century."

SHORTLY AFTER THE 9/11 terrorist attacks, Whorton was flying as the air control officer with VAW-117, the Wallbangers, when he heard a chilling radio call from a ground controller in Afghanistan.

"Banger, I have troops in contact," said the controller, who authenticated his identity as American by providing Whorton with the proper security codes. "Require assets immediately."

"He was very calm," Whorton recalls of the controller, whose name and military branch remained unknown. "But every time he keyed the radio, I could hear incoming fire."

Whorton relayed the news to his combat information center officer. Though Hawkeye naval flight officers are unable to see targets and activity on the ground, they have a line on all the airplanes in the area: current position, assigned target, weapons, fuel status, and so on. At the moment, a pair of Hornets armed with GBU-12 laser-guided bombs were coming off a tanker and the two other F/A-18s in the division were about to refuel. After getting an okay from his combat information center officer, Whorton dis-

patched the fighters to provide urgently needed close air support.

After radioing orders to the Hornets, Whorton watched four friendly aircraft symbols cross his radar screen. A few minutes later, he got a call from the lead Hornet: "We're Winchester [out of ammunition] and RTB [returning to base]," the pilot reported.

"Do you require additional assets?" Whorton asked the ground controller.

"Negative. I'm very good right now," came the radioed reply, which was no longer competing with the sound of incoming gunfire. "Have a good day."

"I felt really good about that," Whorton says. "We're not frontline guys. But it was good to know that, after all of our training, my job made a difference and we were able to help the guys who were under fire. The system worked the way it was supposed to."

The Hawkeye, of course, wasn't designed for close air support, but time and again during the fighting in the Gulf, ground troops advanced so rapidly that they passed beyond radio contact with the units that were supposed to coordinate close air support for them. Early on in Iraq, E-2s were pressed into a stopgap role as airborne communications relays between ground forces and the U.S. Army's Air Support Operations Center. But because the battleground was so fluid and so many airplanes had to be re-routed so quickly, Hawkeyes were given more latitude to pair warfighters with targets.

"If the Hawkeye hadn't been there, I think the [Air Support Operations Center] would have failed," says Lieutenant Commander Brent Trickel, an E-2 naval flight officer who served as the Navy's only officer in the Air Support Operations Center during the first few weeks of the war. "It would have been shut down. I don't think you'll find a more flexible platform than the Hawkeye."

These days, in addition to traditional airborne early-warning duty, Hawkeyes are being asked to push their noses clos-

A gaggle of Hawkeyes operating out of the Naval Air Facility in Atsugi, Japan, takes to the air during a training mission.

er to the fight to coordinate ground attacks and close air support. Theoretically, these missions ought to be covered by the daily Air Tasking Order, which details every sortie to be flown that day. "But everything never goes exactly according to the ATO, which is why you need an E-2," says Weathers. Targets move. Attacks are launched unexpectedly. Engines go sour. Bombs fail to explode.

For many years, the E-2 was naval aviation's version of the pleasant girl in high-school who was everybody's friend but never got asked to the prom. Light on sex appeal, the Hawkeye was ignored by the fighter jocks, who, as the expression goes, like to fly at 1,000 miles per hour with their hair on fire. Times have changed.

WILLIAM H RAMSEY/US NAVY

JAROD HODGE/US NAVY

The E-2 has shown what it can do in shooting wars, and as members of the Hawkeye community have risen in the naval hierarchy, the airplane's reputation has gone up accordingly. "We go through training exercises side by side with [Hornet pilots], so they're used to us," says Carmen. "They know that we understand how airplanes fly—that they can't turn on a dime or fly without fuel. So they like hearing from us. We're like an extension of them. We just fly slower than they do."

For now, the Navy plans to start retiring its E-2Cs in 2013, when the first of the new E-2Ds are scheduled to reach carrier squadrons. (Mexico, France, Egypt, Japan, Taiwan, and Singapore also fly Hawkeyes, but so far none of them has placed an order for the E-2D.) D models will look almost identical to their predecessors, and they should carry the E-2 well into its senior years. "I'm looking forward to the E-2E," says Northrop Grumman vice president Tom Vice. "And there are plenty of other letters in the alphabet after that."

The largest aircraft in the naval air wing, the E-2 folds its wings for maneuvers on the flight deck.

How Things Work:

Thrust Vec

BY JIM MATHEWS | ILLUSTRATION BY JOHN MACNEILL

REMEMBER THE SCENE IN THE MOVIE *TOP GUN* WHEN NAVY PILOT PETE "MAVERICK" MITCHELL GETS THE UPPER HAND ON HIS INSTRUCTORS BY SLOWING DOWN, PULLING UP THE NOSE OF HIS F-14 TOMCAT, AND WATCHING HIS OPPONENT FLY RIGHT BY? THE IDEA WAS TO GET A QUICK, UNEXPECTED POSITION BEHIND THE BAD GUY, PUTTING MAVERICK (PLAYED BY TOM CRUISE) AND HIS TRUSTY SIDEKICK GOOSE INTO PLACE TO WIN THE ENGAGEMENT.

Real fighter pilots will tell you that what Maverick does is a showoff move that bleeds off so much energy that you're vulnerable to getting shot down yourself. What a pilot really needs is a way to quickly get in the right position to fire at the enemy. Today's most maneuverable fighters use thrust vectoring, which can make a jet turn faster and more tightly.

Powered by Pratt & Whitney F119 turbofans, each with 35,000 pounds of thrust, the F-22A—the Air Force's newest fighter—sports a nozzle that can direct exhaust thrust up or down as much as 24 degrees.

The advantage to pilots is superior low-speed and high angle-of-attack maneuverability, compared to conventional-thrust aircraft, says Second Lieutenant Aaron Hoke, a propulsion engineer on the U.S. Air Force team that manages the Lockheed Martin F-22A Raptor program at Wright-Patterson Air Force Base in Ohio.

"Our [one-on-one] tactics have changed to incorporate the 'post-stall' regime, where other aircraft cannot operate," explains Captain John "Rocks" Wagemann, who flies the F-22A in the First Fighter Wing at Langley Air Force Base in Virginia. Thrust vectoring enables the pilots to fly up and over in a very tight arc, Wagemann says, and "gives us the nose authority to turn the jet while the wings are stalled, similar to a controlled flat spin."

Thanks to advanced computers and flight control systems, pilots don't have to think about choosing vectoring or executing specific steps to perform a maneuver. They simply point the airplane where they want, and the onboard systems automatically coordinate the right combination of flaps, rudder, elevator, and nozzle angle. "The F119's vectoring nozzle is integrated into the F-22 flight control system" so that "the pilot doesn't control the nozzle independently," says Chris Flynn, Pratt & Whitney's F119 director.

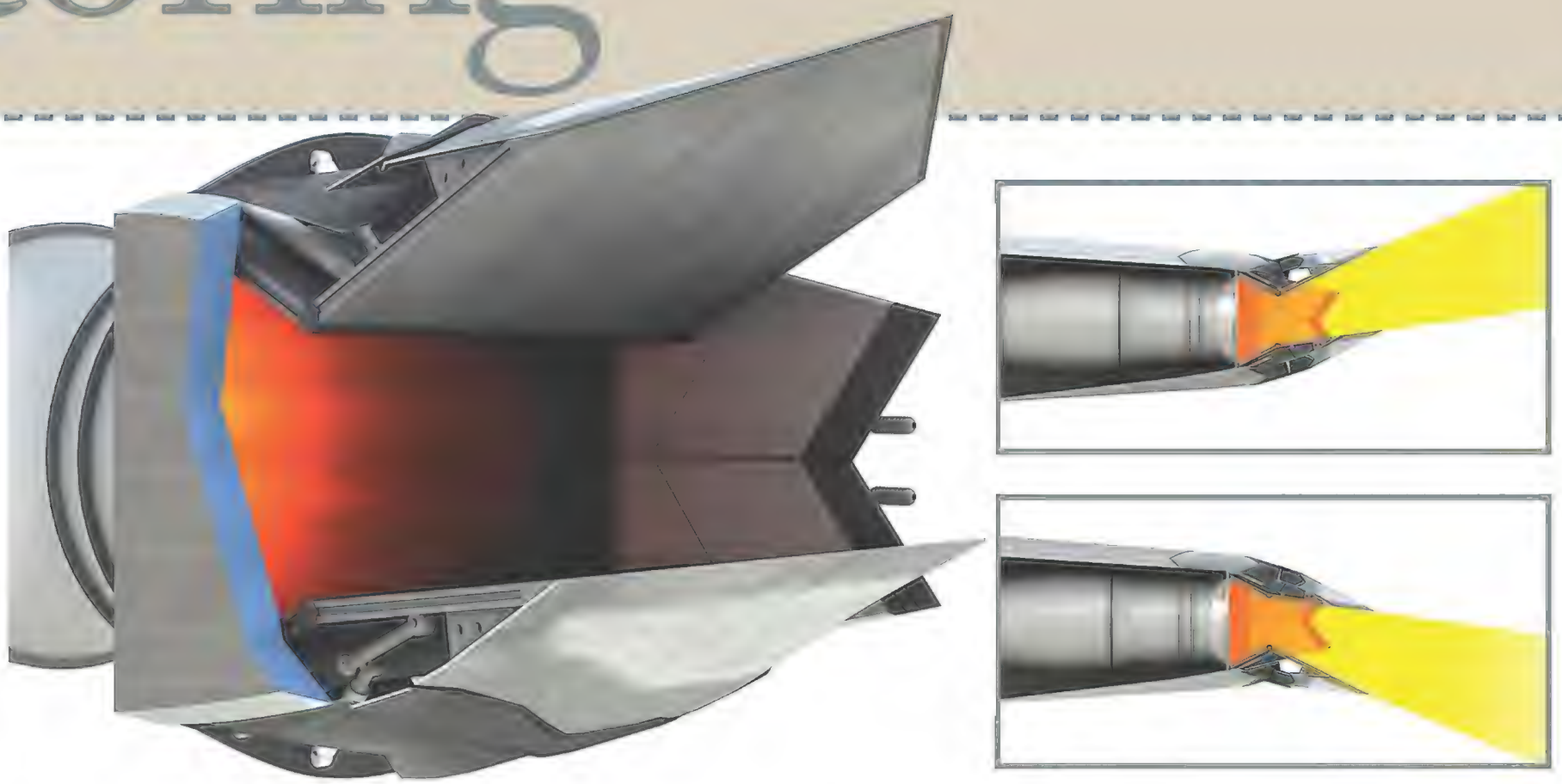
Flaps in the engine nozzle point up or down to "steer" the jet exhaust, making the airplane more responsive and maneuverable. In a two-engine airplane like the F-22, directing the exhaust from both engines upward points the nose up, while reversing the direction points the nose down. The F119 engines are designed to vector in the same direction and by the same amount. The nozzle is said to be "two dimensional" when the shape of the throat is rectangular.

NASA DRYDEN FLIGHT RESEARCH CENTER

TSGT MICHAEL AMMONS, USAF

These thrust-vectoring airplanes (from left, a NASA F/A-18, the X-31, and an Air Force F-16) gathered data helpful in designing the twin-engine F-22A (right).

toring



Hydraulic actuators operate two sets of flaps to direct the thrust of the Pratt & Whitney F119 turbofan. Inner, convergent flaps narrow the passage of the engine exhaust, while outer, divergent flaps swing either up or down (right) to direct the exhaust, giving the F-22A an edge over other fighter aircraft in maneuvering.

Flight tests of thrust-vectoring designs began in the early 1990s with airplanes like NASA's modified F/A-18 and F-15, the Rockwell/MBB X-31, and a modified Air Force F-16. In 1994, the X-31 demonstrator was fitted with what German program managers called a "poor man's thrust vectoring nozzle"—three paddle-like vanes that pushed into the exhaust stream—and the results were spectacular. Without thrust vectoring, the X-31 lost twice as often as it won against the F/A-18 in mock combat; with it, the X-31 didn't lose once in 129 matches.

Theorists say air combat could be changed by the introduction of some maneuvers unique to thrust vectoring. A high angle-of-attack descending spiral is one. At a high angle of attack, a rudder loses its effectiveness, and being able to rely on thrust vectoring would let a pilot enter what's essentially a controlled flat spin, yawing the airplane around to aim at a target without worrying about the rudder. The pilot also gets extra maneuverability at high altitudes, says Wagemann, "where the air density is so low that the flight control surfaces become significantly degraded." Then there's the super-tight J-turn, or even a modified hammerhead, in which an airplane appears to briefly fly backward.

One common misconception about thrust vectoring involves the flashy cobra maneuver, also known as Pugachev's cobra, after Russian pilot Viktor Pugachev, who first wowed crowds with it in a Sukhoi Su-27 at the 1989 Paris Air Show. The maneuver is not an example of thrust vectoring. If the pilot is skilled enough, he can do the cobra in nearly any type of U.S. jet fighter. In essence, the pilot abruptly pulls the control yoke full aft while flying around 300 knots—about 345 mph—and thus pitches the nose up dramatically so the airplane is nearly standing on its tail. Just as abruptly, the pilot pushes the stick forward, dropping the nose back down. When the maneuver is flown correctly, with little change in altitude, the effect is like the striking of a cobra's head.

Right now, the F-22A and the Russian Sukhoi Su-37 and Su-30MKI (flying with the Indian air force) are the only fighter aircraft with two-dimensional thrust vectoring nozzles.

More sophisticated designs, which have yet to fly beyond the testing stage, feature nozzle flaps that can move 17 to 20 degrees in nearly any direction, resulting in maneuvers around both the pitch and yaw axes. Both major U.S. fighter engine makers, Pratt & Whitney and General Electric, tested multi-axis vectored nozzles about a decade ago for an Air Force demonstration program.

Until thrust vectoring becomes more widespread, few will enjoy that extra edge—and that's just fine with U.S. pilots. "Thrust vectoring provides such a significant advantage in the visual maneuvering arena that I rarely find myself in a defensive position," says Wagemann. "When we start defensive, for training, you are almost always able to transition to offensive without getting shot."

The Things

HOW AN UNREMARKABLE CONVAIR C-131H TRANSPORTED COPS, PATIENTS, PRISONERS, AND GERALD FORD

BY THOMAS DEFRANK

R. SULLIVAN/J.G. HANDELMAN COLLECTION

It Carried

AN AGING C-131H with a stately past lifted off from an airfield in Saskatchewan, Canada, last spring on a most unceremonious mission. Leveling off at about 3,000 feet, the twin-engine turboprop dumped 1,750 imperial gallons of red-tinged flame retardant on burning pine and spruce forests in the province's northern reaches. Fifty-three years after rolling off an assembly line in San Diego, California, the Convair works as a "water bomber" for the Canadian government.

It's the latest incarnation for an airplane that once enjoyed the world's most famous call sign: Air Force One. Now it answers to the more prosaic Tanker 475. The Convair is a bare-bones workhorse, its executive seating having been ripped out decades ago. "From our standpoint, it's all extra weight," explains Steve Roberts, executive director of Saskatchewan's Fire Management & Forest Protection Branch, which bought the airplane in March 2006.

The hardy Convair has had a storied career of transport missions. Its 25,046 airframe hours include service with the U.S. Air Force, Navy, Department of State, and Marshals Service; the Peruvian National Police; and a Michigan cargo company. Among transports, it enjoys an exalted distinction: For at least a day, it was the presidential aircraft. On October 26, 1972, President Richard Nixon used it for a weekend campaign trip to Huntington, West Virginia, and Ashland, Kentucky. "I thought this airstrip was a little short," Nixon told the crowd at the Huntington airport. "That is why we had to bring the Convair in."

As vice president, Gerald Ford (with pipe), toured the country in a VC-131H, one of several in the executive fleet.

DAVID HUME KENNERLY PHOTOGRAPH COURTESY GERALD R. FORD LIBRARY

DAVID HUME KENNERLY PHOTOGRAPH COURTESY GERALD R. FORD LIBRARY

Ford (at foot of steps) joked that Air Force Two was "horrible" – slow, noisy, and austere. But it got good gas mileage.

Its most frequent VIP customer, however, was Vice President Gerald Ford, who flew on it dozens of times from the fall of 1973 until he succeeded Nixon on August 9, 1974. As a reporter for *Newsweek* magazine, I'd been assigned to cover Ford, with orders to "live with him"; my editor was convinced the Watergate scandal, which had broken in the summer of 1972, would force Nixon to resign and that Ford would soon be president. It was an exhilarating experience for a 28-year-old rookie—but not because of Ford's airplane.

Those big, powerful Allison engines were unbelievably noisy, and the cabin wasn't exactly plush. With a range of 1,500 miles, the Convair couldn't get Ford to the West Coast without refueling. Even shorter day trips, which he favored, were excruciatingly slow. On an early flight, as the pilots engaged the engines, a Secret Service agent, poking fun at the airplane's lack of speed, yelled: "Quiet, please. Prepare to activate slingshot." From then on, the airplane was known as Slingshot Airlines.

Ford had mixed feelings about his little Air Force Two. In 1976, he inscribed a photo of the two of us chatting aboard his Boeing 707 Air Force One: "Sure does beat Air Force #2." Twenty years later, in another of our interviews, he jokingly called the Convair "that horrible airplane." Yet the Convair fit Ford's distinctly un-imperial style. He liked its lack of ostentation and the fact that it wasn't a gas-guzzler, like the big jets in the VIP fleet.

"That little plane was pure Gerald R. Ford: simple, comfortable, down-to-Earth, and reliable," says retired Colonel Bob Blake, Air Force assistant to Ford when he was vice president and president.

The Convair's registration plate lists its date of manufacture as September 20, 1954, and its serial number as 217. The Air Force christened it a C-131D and nicknamed it "Samaritan" because in its early years it was used for medical evacuations. A dozen years after joining the Air Force fleet, the airplane was outfitted with 2,900-horsepower Allison T56-A-4 engines and fancier interiors and converted to an executive transport. It (along with three other Samaritans) was redesignated a VC-131H and assigned to VIP transport duty at Andrews Air Force Base, Maryland, outside Washington, D.C. In 1978, after 24 years with the Air Force, the Convairs were transferred to the U.S. Naval Reserve. Two years later they were moved to Fleet Logistics Support Squadron 52 (VR-52) and then VR-48, based, ironically, directly across the runways from where they had been stationed at Andrews for 12 years.

"I fell in love with the aircraft," recalls former VR-48 commander Ryan Swah, now a FedEx pilot. "It was reliable, did a nice mission, and never broke down. But it vibrated a lot and sure was noisy."

In 1990, the squadron converted to McDonnell Douglas C-9 jets and transferred its three Convairs to the state department's Bureau of International Narcotics, where on February 1, no. 42815 began a new life as a drug interdiction transport. But not before the galley and the rest of its executive features were stripped out and replaced with industrial-strength seating for about 48 soldiers and drug enforcement agents. The airplane was re-registered N7146X.

Assigned to the state department's air wing at Patrick Air Force Base in Florida, the Convair flew missions in Belize, Bolivia, Colombia, Guatemala, and Peru. Because it was nominally under the control of the Peruvian National Police, the airplane became PNP-025. By March 1994, after the state department acquired bigger and faster jets, the Convair, now painted light gray with black trim, was retired and flown to the boneyard at Davis-Monthan Air Force Base, outside

ERIC FORTIN

In a civilian capacity, the Convair C-131 is designated the 240, 340, or 440, with the latest variant being the 580 (right).

JAY N. MILLER COLLECTION

JOHN HEGGBLOM

Regional U.S. carriers such as Frontier (above) and Mohawk used Convairs for short routes in the 1960s and 1970s.

Tucson, Arizona. In late 1995, Ford's airplane was acquired by the justice department's U.S. Marshals Service, which transports thousands of prisoners and illegal aliens each year.

"It didn't cost a cent," says Dick Rake, now chief pilot for the marshals' Mesa, Arizona office. The General Services Administration, he explains, "was getting rid of it, and gave other government agencies first crack at it. It was a beautiful airplane, in surprisingly good shape."

The Federal Aviation Administration re-registered the aircraft N723ES. Even so, the Marshals Service needed only one airplane, and its other Convair had logged fewer hours. So Ford's airplane stayed parked in the desert another four years, partially cocooned in sealant to protect its windows and engine nacelles.

In 1999, the airplane finally was rescued from oblivion by IFL Group, a Pontiac, Michigan cargo outfit that bought it and two other 580s at a government auction for slightly more than $1 million. An IFL team drained the preservatives from the Convair's fuel and oil systems, changed filters, and installed an avionics ferry package to fly it home.

"Overall, it was in reasonably good shape," says IFL's Mark Bunner. "The engines were in good condition. The props had aged but were functional." All that remained of the interior was military-style "parachute" seating along the bulkheads. As it turned out, the new owners never flew it. The airplane wasn't certified for commercial service, and the retooling costs were prohibitive. It sat in Michigan for seven years.

In the spring of 2006, the Saskatchewan government bought the airplane and began remanufacturing it for firefighting. Overhauled at Kelowna Flightcraft in British Columbia, Tanker 475 had its front door and most of the windows removed and was upgraded with new avionics, wiring, hydraulics, electronics, Allison D-22 engines, and yet another registration: C-GSKQ.

Last fall, the airplane was flown to Abbottsford, British Columbia, where a tank for flame retardant was mounted on the belly before it flew to its new home at La Ronge, near Saskatchewan's forests. There it joined two other C-131Hs used as water bombers. All the work at Kelowna, which converted Ford's airplane into a CV580a, has extended its life. "We intend to use these aircraft for another 20 years," says Roberts. He cites the reliability of the airframes, the relatively low number of flight hours when purchased, and the low operational use projected for the fleet: typically 100 flight hours a year for each airplane.

So three-quarters of a century later, the one-time flying ambulance and hauler of presidents will come full circle, ending its career as a first responder.

Ford's old airplane (left; registration plate inset) was converted into a Canadian "water bomber" like the 580 below.

SASKATCHEWAN MINISTRY OF ENVIRONMENT-FIRE MANAGEMENT AND FOREST PROTECTION BRANCH (3)

LOCKHEED'S MISSING L

BETWEEN THE F-80 AND THE F-104, A SUPERSONIC PIONEER FOUGHT

ON APRIL 22, 1952, dozens of journalists and approximately 2,000 military personnel watched as a 31-kiloton nuclear bomb exploded above the Nevada Proving Ground. Operation Tumbler-Snapper, as the series of atmospheric tests was called, was designed to evaluate the vulnerability of parked aircraft to an atomic bomb blast. Among the aircraft gathered there was one of the hottest-looking fighters ever built: Lockheed's XF-90.

The needle-nose fighter followed Lockheed's F-80 Shooting Star, the first U.S. jet fighter to see action, and was an important precursor to the "missile with a man in it," the F-104 Starfighter. And though only two were built, the XF-90's dashing good looks earned it movie-star status throughout the 1950s—far beyond its operational life—attracting readers and advertisers to prominent aviation periodicals and comic books of the time. As a single-engine F-90B, it made a splashy cover for the September 1953 comic book *Blackhawk*. Thereafter, a generation of young Boomers dazzled by futuristic aviation technology awaited each new adventure of American pilot Blackhawk, his buddy Chuck, and their coalition of international fighter jocks manning a fleet of six sleek F-90Bs in the quest to take down the "Red Tide" thugs of the atomic age.

The F-90 was the first U.S.-built, swept-wing jet to use afterburners as standard equipment and have wingtip fuel tanks and a fully adjustable fin and stabilizers. Fowler flaps and leading-edge slats improved airflow over the wings, making the F-90 one of the pioneers in 35-degree swept-wing technology. In tests, the hot rod exceeded Mach 1 fifteen times.

So how did such a capable aircraft, one that so captured the public's imagination, become atomic bomb test fodder?

AFTER WORLD WAR II, the U.S. Army Air Forces needed a "penetration fighter," capable of escorting bombers to and

COURTESY R. PUFFER, EDWARDS AFB

THE COLD WAR...IN ITS WAY.

BY JORGE AND KAREN ESCALONA

As a "penetration fighter," the XF-90 was meant to do it all: destroy ground targets, withstand anti-aircraft fire, outrun enemy fighters, and escort bombers to their targets. It ended up as atomic bomb test fodder.

from their targets. The early jet fighters had been far from perfect, and their notorious fuel consumption decreased their range. In 1945, the AAF issued a request for a fighter with a combat radius of about 900 miles. Competing for the contract against McDonnell's XP-88A and North American's XP-86C, Lockheed's team, headed by Clarence "Kelly" Johnson and Willis Hawkins, went through 65 versions before settling on the swept-wing design of the XP-90. (In 1948, the P designation, for "pursuit," was changed to F, for "fighter.")

Johnson pushed the group to produce two twin-engine prototypes, whose appearance inspired the team to coin the nickname Big Broad-Breasted Turkey. "Its front view with the broad fuselage and side inlet ducts gave it the broad-breasted look," says Jim Beach, the engineer who pioneered the XF-90's canopy actuation and ejection system. "Jim Pray, the windshield designer, dubbed it a 'turkey' due to its wimpy engines."

Testing of the "wimpy" engines began on the ground at Burbank, California, but the first XF-90 was trucked to the North Base of Muroc Air Force Base, now Edwards Air Force Base, in 1949 for flight testing by Tony LeVier, Lockheed's chief test pilot.

Lockheed assigned flight test engineer Ernest Joiner to the project. "Very little was known at that time about what happened to an airplane when it exceeded the speed of sound," Joiner recalls. "There were all kinds of weird ideas that the airplane would be subjected to very high structural loads. This lack of information contributed to the XF-90 being the strongest airplane anyone had ever seen. Of course, the sound barrier had been broken by Chuck Yeager in the X-1 research aircraft in October 1947, but [that didn't happen] in time to have much influence on the design of the XF-90."

"The important thing was that the -90 liked to fly," Lockheed's chief test pilot Tony LeVier wrote in 1954. "That's always the mark of a good airplane."

It fell to Chuck Buzzetti, a research engineer in the flight test organization, to evaluate the strain gauges used to measure the wing loads on the heavy aircraft. "The main I-beam of the F-90 resembled a bridge girder," says Buzzetti.

Due, in part, to its aluminum skin—four times more stress-resistant than the standard alloy of the day, and a feature that enabled the aircraft to withstand 12 Gs—the single-seat fighter weighed as much as a DC-3, and was almost 71 percent heavier than an F-86, so its Westinghouse engines were seriously underpowered. The team could only hope the airplane would survive its test flight.

"I'll never forget one flight Tony made on May 17, 1950," recalls Joiner. "It was one of the times when Kelly [Johnson] was there. The test program was to conduct power-on dives to work up to the so-called sound barrier. We were on the radio with Tony as he made a dive at fairly low altitude. We could see the airplane on the other side of the dry lakebed. It disappeared in the haze. At that moment we heard a tremendous explosion. There is no doubt that both Kelly and I

OPPOSITE: COURTESY R. FRIEDRICHS; ABOVE: LOCKHEED MARTIN

thought that the airplane had augured in. I was afraid that Kelly was going to have a heart attack. Within a very short time Tony called in on the radio. Talk about relief! He had dived the airplane to Mach 1.12 and everything was fine. You have to realize that we hadn't heard a sonic boom before. I'm not sure about Kelly but there's a good chance he hadn't heard one either. Tony went on to exceed the speed of sound a number of times, and the XF-90 handled fine. It certainly experienced no problems structurally."

Despite the aircraft's attributes, the need for an all-purpose fighter was declining. "It had become obvious to everyone that this do-everything fighter was not a good idea," says Joiner. "I guess you could say it was a jack of all trades but master of none."

COURTESY R. FRIEDRICHS

In 1950, the Air Force awarded its contract to the McDonnell XF-88A. With the outbreak of the Korean War, however, the Air Force needed combat airplanes in a hurry, and looked to the existing F-80, and the F-86, which was already in production. The exhausted Lockheed team turned to other projects. LeVier would later observe, "Sometimes it is better to chalk an airplane off as experience and go on to something else."

The company retired the two prototypes to careers as structural test subjects. The first prototype was tested to destruction at the National Advisory Committee for Aeronautics Laboratory in Cleveland. The second XF-90 (along with other aircraft, including a B-45, a B-29, F-47s, and B-17s) was sent to the Nevada Proving Ground for use in a nuclear weapons test. Secured about a half-mile from ground zero, and nose-in to the first two blasts, the XF-90 survived a one-kiloton shot on April 15, 1952, with undamaged wings, but sustained enough dents and cracks—not to mention the buckling of a fuselage fire door—that it would have taken approximately 106 hours to repair. A second, 31-kiloton blast a week later bent the aircraft's nose. For the third blast, 19 kilotons detonated on May 1, the XF-90 was positioned perpendicular to the shock wave. The blast severed the tail and blew the landing gear from the wing; the main wing structure was buckled and scorched.

The Nevada Test Site later suspended above-ground tests.

Part of an exercise to determine the vulnerability of parked aircraft to atomic bombs (left), this XF-90 was thought to be destroyed. Its remains were recovered from the desert in 2001.

COURTESY JAMES SEALS, FLUID TECH, INC.

A Fluid Tech crew member blasts away 40 years' worth of radioactive nest debris left by white-tail antelope squirrels (right). In prouder times, the XF-90 had been the star fighter of DC Comics' Blackhawk Squadron (below).

COURTESY JAMES SEALS, FLUID TECH, INC.

After a 5.3-kiloton underground blast, in December 1963, the XF-90's contaminated, cracked, and partially scorched frame was moved to NTS Area 11, where it was used in Broken Arrow exercises in which crews trained for recovery of a downed airplane with a nuclear payload.

The aircraft was officially documented as destroyed—"vaporized, people thought," says Robert E. Friedrichs, a physical scientist at the National Nuclear Security Administration's Nevada Site Office. But flying over the test site a few years later, Ernest Joiner saw something unexpected: "Looking down, we could see the XF-90. It appeared to be intact."

Friedrichs recognized the fighter's historic significance. "There were some things about that airplane that I thought were phenomenal," says Friedrichs. "The fact that the aircraft survived at all is a story that needed to be shared."

When Friedrichs served as a scientist at the Nevada Test Site, he got a first-hand look at the remains of the airplane as it sat on a dry lakebed over several decades. "Since only two were built and one was destroyed, in the late 1980s I got the process started of getting this aircraft preserved for presentation in a museum," he says. For 13 years Friedrichs forged through bureaucratic snags: He assessed the aircraft's historic value, contacted museum curators, organized funding, and found contractors to retrieve and decontaminate the airplane after five decades of radioactive decay.

J.L. ESCALONA COLLECTION

In 2001, Friedrichs found a home for the XF-90 prototype: the National Museum of the U.S. Air Force, near Dayton, Ohio. The museum's director, retired Major General Charles D. Metcalf, recognized the important role the aircraft played in the beginning of the cold war as an experiment in early atmospheric testing of atomic bombs. "[The XF-90] had a lot of firsts," he says, adding that the fighter will be used in an exhibition on "the people and events during the very inception of the cold war."

Although the sleek fighter never made it into production, its participation in three atmospheric atomic bomb tests helped in waging the cold war. In a 1990 letter to the Nevada Division of Historic Preservation supporting the XF-90's conservation, Donald Elle of the Department of Energy noted: "Information derived from [the Tumbler-Snapper project] continues to be used in aircraft design and operational deployment today."

Friedrichs met with radiation programs director James Seals and Fluid Tech, Inc. to figure out how to deconstruct, survey, and decontaminate each piece of the aircraft. Although Fluid Tech had experience in all types of contamination control, this was the first time the company would clean an aircraft.

Workers found the fuselage inhabited by a thriving colony of white-tail antelope squirrels. Because of the possibility the animals were carrying Hantavirus, Seals used a combination of bleach and sandblast to eradicate 40 years' worth of nest debris. His crew, sweltering in full protective gear in the desert heat and carrying radiation detectors, scoured every surface, penetrating the smallest crevices to eradicate plutonium residue. During the summer, the crew disassembled and decontaminated the aircraft at night. "By midday it's too hot," Seals says of the desert, "even for the snakes." Temperatures plummeted in the winter. Despite the extremes, the crew members completed the job within a year.

Along the way, they made a surprising discovery. The original Westinghouse engines had survived. "We'd never taken apart a jet engine before, but when we pulled them out, the turbines still turned," says Seals. "You could push a turbine fin and spin those engines real easy."

In 2003, a C-5 transport flew the decontaminated XF-90 parts from the Nevada Test Site to Wright-Patterson Air Force Base. It will take a year to reassemble the aircraft, says restoration division chief Roger Deere, who will prepare the airplane for exhibition. (While the XF-90 awaits restoration, visitors can see the fighter by taking a special behind-the-scenes tour.)

Although one aircraft on the Nevada Test Site, a B-17 bomber, was rebuilt and flown out, Friedrichs was hesitant to see someone try to fully restore the XF-90. "When you only have one left, you really don't want to take the chance of flying it and possibly losing it," he says. Instead, says Deere, "The exhibit will tell the story that the XF-90 has been through three nuclear blasts." He admits, "It would be a major chore to restore it to a good, decent-looking airplane." Instead, says Friedrichs, the public will see the XF-90 "exactly as it sat out here in the desert for half a century."

FIND OUT MORE www.airspacemag.com TO SEE VIDEO OF THE XF-90, VISIT OUR WEB SITE.

The Few, the Brave,

TO FACE THE ENEMY IN WORLD WAR I, PILOTS FIRST HAD TO SURVIVE FLIGHT TRAINING. BY TOM LeCOMPTE

Dear Mother and Dad:
This looks cheerful, but it is much more cheerful than it looks.... After 12 hours on BE2c's I took one up and smashed it to bits. Am not hurt—just messed up a bit.
—Letter home, March 16, 1918

Frederic Barr Shaw had reason to be cheerful. He was alive, and would fly again, unlike scores of fellow cadets in Britain's Royal Air Force. The year before, Shaw had recorded in his journal that at the field where he received primary flight training, there were an average of three crashes a day. In most cases, the pilot escaped with only cuts and bruises, but over the course of several months, many were seriously injured or killed.

During most of World War I, pilots stood a greater chance of being killed during training or in accidents than in combat. Aviation, after all, was only a few years old when the war broke out in 1914. From a few dozen types of airplanes and a few hundred pilots around the world, it grew in a matter of years to include hundreds of types of aircraft and thousands of pilots. In 1917, British manufacturers rolled out nearly 14,000 aircraft—a staggering number, considering that just three years earlier, only 193 had been built in the course of a year. With hostilities at full bore, the pressure to produce airplanes and pilots for combat resulted in unreliable machines flown by men who didn't know how to operate them. Training time was slashed from six months to three in order to double the number of pilots for the Royal Flying Corps and the Royal Naval Air Service (they merged

In the years surrounding World War I, aviation was a hazardous occupation. A Handley Page O-400 (opposite) hit a tree while taking off with mail from Marquise, France, in April 1919, killing three.

in 1918 to become the Royal Air Force). In the letters and diaries of pilots like Shaw, the process of training emerges as a raw and dangerous business.

A terrible day. Harold Coo, Langston and Lt. Cdr. Murray were killed. Chesterton had two legs broken and MacLaren concussion of the brain. Many crashes. Coo and Langston collided at 500 ft. Murray and Chesterton in dual flight came to earth in a spinning nose dive... Getting awfully fed up on the flying game. Feeling blue.
—Shaw's journal, January 22, 1918

Shaw considered himself the ideal candidate for the Royal Naval Air Service, even though he had likely never seen an airplane, much less flown in one. Born in Canada, he was living in Kansas City, Missouri, when he volunteered to become a cadet, figuring his year of college and classical piano training would impress recruiters looking for good breeding and social standing. After several months of letters and telegrams to a recruiter in Ottawa, Shaw was finally accepted, and in October 1917 he was told to go to Halifax and catch a boat bound for England. He was assigned to Squad 16-A, along with about 40 other recruits, at the Royal Naval College in Greenwich. There, his month-long training consisted of lectures on flight theory, meteorology, navigation, wireless telegraphy, and engine mechanics. The courses, he wrote his parents, were terribly boring and seemed to have little to do with flying. "Rotten, all of them," he complained in a letter home. Shaw was then transferred to Vendome, a small French town about 120 miles southwest of Paris, to begin flight training.

The first flight with an instructor piloting is called the "joy flip"—I believe they side-slip, nose spin and generally try to scare you green. I am looking forward to it.
—Letter home, November 9, 1917

About the same time Shaw arrived in Europe, John McGavock Grider was transferred from the U.S. military air service to the Royal Flying Corps. Grider was a divorced cotton farmer from Arkansas with two young sons and a taste for adventure. Like Shaw, he wrote about his training and the catastrophes he witnessed at British flight schools. Together, their accounts draw a vivid picture of the risks that men of their time took to become military pilots.

A horrible thing happened today. We were all out on the tarmac having our pictures taken for posterity when somebody yelled and pointed up. Two Avros collided right over the airdrome at about three hundred feet. God, it was a horrible sight. We didn't know who was in either one of them. I was glad I was sitting next to Cal. They came down in a

the Lucky

ALL PHOTOGRAPHS COURTESY TOM LECOMPTE EXCEPT WHERE NOTED

Frederic Shaw wrote letters home about his crash in a BE2c biplane in England (left). Above: Shaw poses with a Sopwith Camel in Marquise, France, after the war. Top: His formal portrait as a 22-year-old Royal Naval Air Service recruit.

NASM (SI NEG: 91-3479)

With a 100-foot wingspan, the Handley Page bomber was one of the biggest airplanes of the war. Right: A pilot and gunner inspect the Handley.

slow spin with their wings locked together and both of them in flames. Fred Stillman was in one machine and got out alive but badly burned and Doug Ellis was in the other one and was burned to a cinder.
—Diary of John M. Grider, February 9, 1918, as edited and amended by friend and fellow pilot Elliot White Springs, in The War Birds—Diary of an Unknown Aviator, *Texas A&M University Press, 1988*

Two weeks later, Grider wrote about another disaster, this one apparently caused by the simplest of mistakes: failure to wear a safety belt.

Montgomery was killed when the pilot fell out of the front seat in an [Avro] in a loop. Montgomery was in the back seat and crawled up into the front cockpit and just had his hands on the controls when it crashed. Think of watching the ground coming up at you for two or three minutes while you wiggle up the fuselage. Makes my blood run cold!

It took one of the largest battles of World War I—and, with more than one million casualties, one of the bloodiest in history—to begin changing the face of military aviation, including better training for pilots. The Battle of the Somme, fought from July to November 1916, cost Britain a total of 782 airplanes and 576 pilots. While it was safer to be a pilot than a soldier in the trenches (the battle killed 420,000 British ground troops), concern over the adequacy of training forced Britain to establish minimum requirements for new pilots: 15 hours of solo flying, a cross-country flight of 60 miles with two landings, a climb to 6,000 feet with 15 minutes of flying level, a dead-stick landing within a circle 50 yards in diameter, and two landings in darkness, assisted by flares.

By 1917, every pilot was required to perform aerobatics: to sideslip, to loop, to imitate a fall out of control, and to perform a dozen other maneuvers. Though most training airplanes were outfitted with dual controls, allowing the student to learn by first following the instructor's control movements, many instructors knew only marginally more than their students. Instructors were simply drawn from pilots either waiting to go to the front or those deemed unfit for it. There was no consideration given to their qualifications or motivation, and they received little supervision. Each instructor taught on the basis of his own experience and attitude. Many instruc-

FIND OUT MORE www.airspacemag.com SEE RARE FILM OF JENNY TRAINERS.

tors, though, were averse to taking risks themselves, so they taught their students primarily how to avoid getting into dangerous flight situations, rather than how to recover from them. As a result, training left the students ill-equipped to deal with the challenges of aerial combat. According to *The Great War in the Air* by John H. Morrow, one British officer complained in May 1917 that most pilots being sent into combat "can't even fly, let alone fight."

Experienced pilots understood that if they manipulated the controls in a particular way, the aircraft would—or at least should—move in a certain way. Yet few could explain exactly why, or which flight controls performed at each stage of a maneuver. Many principles of flight were simply a mystery, so if anything unexpected happened, a pilot was apt to lose control, and his ability to regain it was often a matter of luck.

Take spins: Before 1916, few pilots unfortunate enough to get themselves into a spin lived to tell of the experience. One pilot who did was surrounded upon landing by others congratulating him on his seemingly fantastic feat. When asked how he did it, he cheerfully replied that he did "everything wrong," by which he meant he did the opposite of what his experience and intuition as a pilot told him. By mid-1917, enough anecdotes had circulated about pilots recovering from a spinning nose dive by pushing *forward* on the control stick rather than the natural inclination to pull back that it motivated British commanders to rethink air training. Under the leadership and inspiration of Major Robert Smith-Barry, the School of Special Flying was opened in Gosport, England, in August 1917.

Before Gosport, many pilots completed training while on active service, during which they were expected to fly more powerful, less forgiving aircraft, often with little or no training on transitioning from one type to another (by 1916, the British flew 76 varieties). They had to perform combat maneuvers while under fire and extreme stress. Gosport emphasized aerobatic and combat maneuvers and also adopted a standard aircraft for training: the British-made Avro 504 biplane. By the end of 1917, Smith-Barry also had introduced the Gosport Tube, a system of voice pipes and headphones for communication between instructor and pupil. Though it came too late in the war to benefit many pilots, Gosport revolutionized flight training in Britain, and according to Richard Hawkins in *The Irish Sword*, a journal of military history, many of the school's techniques became part of the foundation of knowledge for generations of pilots.

Shaw did not have the benefit of the Gosport Tube for his first "flip," as he and his comrades called a flight. After a week of sitting around Vendome watching crash after crash, he finally got in the air, taking off on Sunday, December 16, 1917, with his instructor in a French-made Caudron G-3 biplane. Sitting in the front seat of the two-seat trainer, Shaw stayed up for 35 minutes and got to a height of 200 feet. At one point, the instructor tapped him on the back and, using a hand signal, instructed him to take the control stick and perform a series of turns. Afterward, the instructor took control and landed the aircraft.

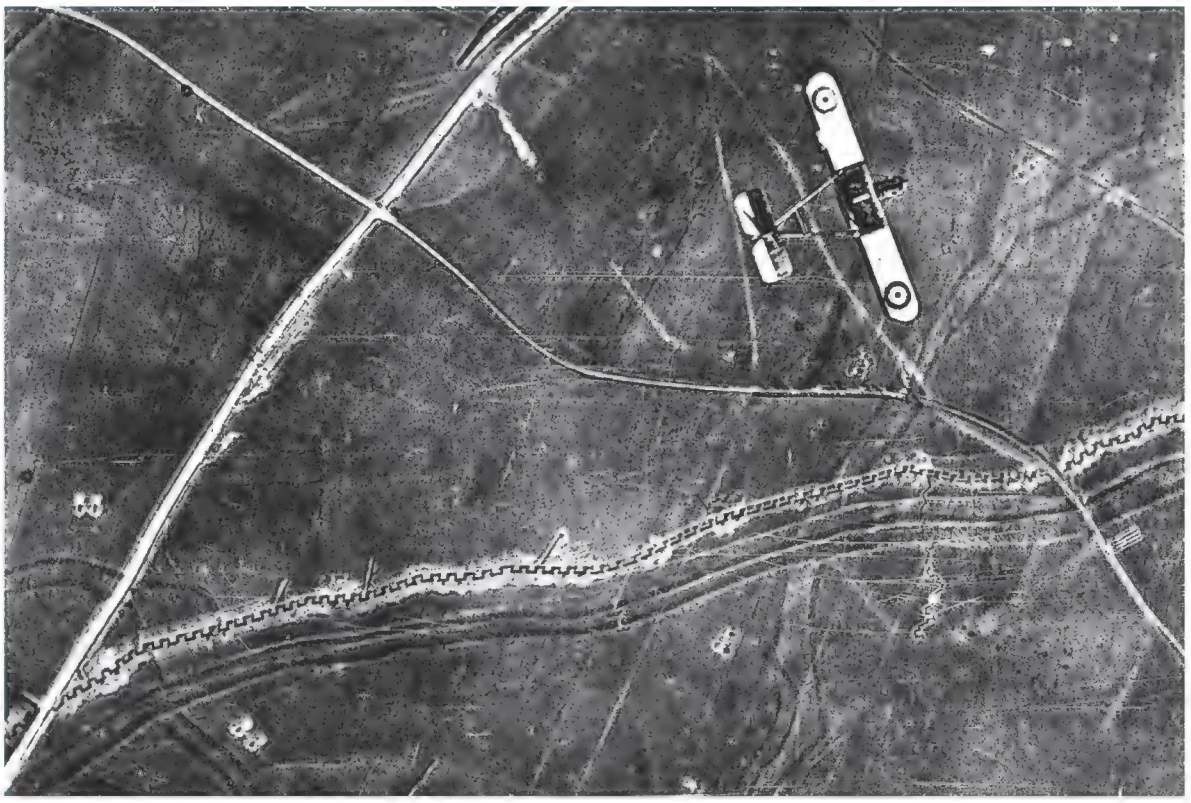
If there was anything remarkable about Shaw's first flight, it was how unremarkable it was. In his letters and journal, there was no romantic reflection on having "slipped the surly bonds of Earth." Despite all the waiting and all the crashes he had witnessed, he expressed no pent-up anxiety, no sense of anticipation, and no wonder at seeing the ground from a new perspective. For Shaw, as for many pilots then, it was all very matter-of-fact.

"If you were a kid and you got into one of these planes, you wouldn't know how scared you should be because you had nothing to compare it to," says Dan Taylor, a radio personality at WCBS-New York and a pilot, restorer, and historian. They would have had good reason to be nervous, says Taylor, who has flown everything from a 1911 Blériot to a 1917 Sopwith Camel. In World War I,

On patrol: American-made Curtiss JN-4Bs (below). "Jennies" were key trainer aircraft for the Allies in World War I.

NASM (SI: 94-9641)

Shaw (at left) takes a break in April 1919 with a colleague at Setques St. Omer in northern France, where he helped work on captured German airplanes.

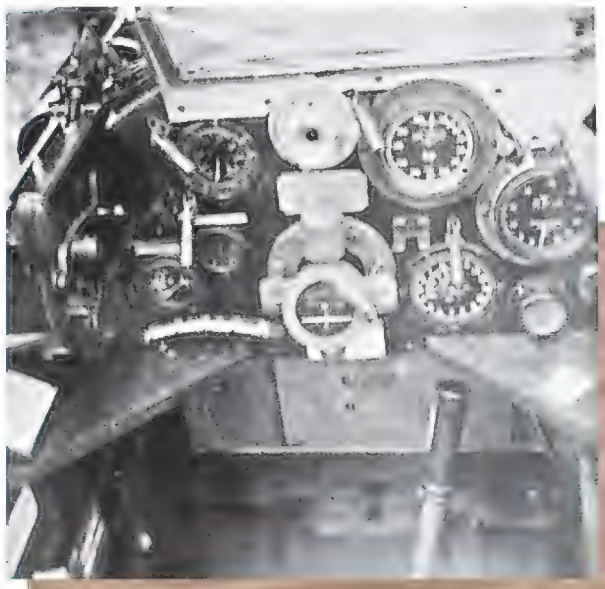


he adds, "all these planes had a lot of drag, so they weren't very aerodynamic. They had the glide ratio of a brick, so you always had to keep an eye out for an open field."

Today, it takes years to design and test a new airplane before it goes into production. But in World War I, airplanes were designed, built, and flown in weeks, with the aerodynamics, flight characteristics, and structural integrity worked out literally on the fly. They were rickety machines, each little more than a wicker seat and an engine, held together with fabric and wire. Even in the best flying conditions, the aircraft were slow and unstable, requiring constant attention.

There was no such thing as "hands off" flying, Taylor explains. "The planes got pushed around by the wind, and the controls on many were heavy. You had to manage the engine much more, and you had to watch your attitude and airspeed to prevent overstressing the airframe." And every airplane was different, even those of the same type. "They each had their own flight characteristics, depending on the individual rigging and what kind of damage the plane had sustained," he says. Another worry was engine failure, so dead-stick landings were a required part of training. "But it did make you a better pilot, because you were more prepared for the unexpected," Taylor says.

That is, if you survived. Before accumulating five hours of flying time, Shaw had wrecked two airplanes, a number that presumably was not considered a problem, given that his instructors allowed him to continue. After three and a half hours of flying with an instructor, Shaw soloed. He flew two circuits around the school's field and landed, as he'd been instructed. Over the next three weeks,



A Farman FE2 (top) soars over trenches and fortifications in France. With both guns and bombs, an Airco DH9a squadron (cockpit inset) trains for battle.

WWW.HISTORICAIRCRAFT.ORG

Shaw accumulated a total of 14 hours of dual and solo time, flying both Caudron and U.S.-made Curtiss JN "Jenny" trainers. In addition to takeoffs and landings, he mastered spirals and S-turns, climbed to 7,800 feet, and made a series of cross-country flights. He was then sent to Cranwell, England, for final training before being assigned to a combat squadron.

When he took off on March 11, 1918, from Cranwell's field in a single-engine BE2c biplane, Shaw had a total of 25 hours of flight time. Soon after, he wrote, the engine "went dud," just as it had many times before. At about 50 feet off the ground and with a large hangar and a line of airplanes looming in front of him, all his options were bad. Deciding not to crash into the hangar and the airplanes, he tried to turn around. He didn't make it. The airplane stalled and nosed into the ground. Shaw was pried bleeding and unconscious from the twisted mass of wood, wire, and cloth. When he came to, he was in the Northern General Hospital in Lincoln, where he was told details of the crash.

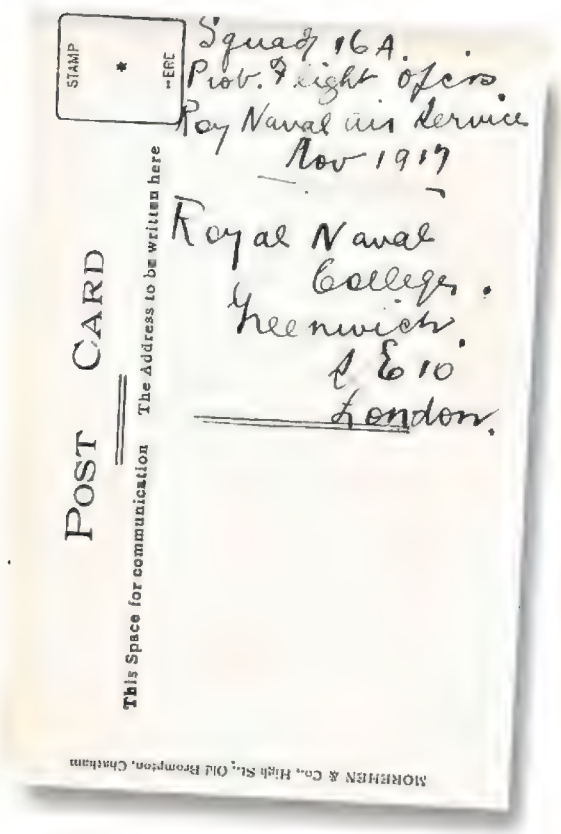
His injuries were minor: a concussion and some cuts and bruises. But he would spend nearly eight weeks at the hospital, apparently lost in the bureaucracy as the new Royal Air Force began operations. When he finally returned to Cranwell, it was June, and he had to repeat much of his earlier training.

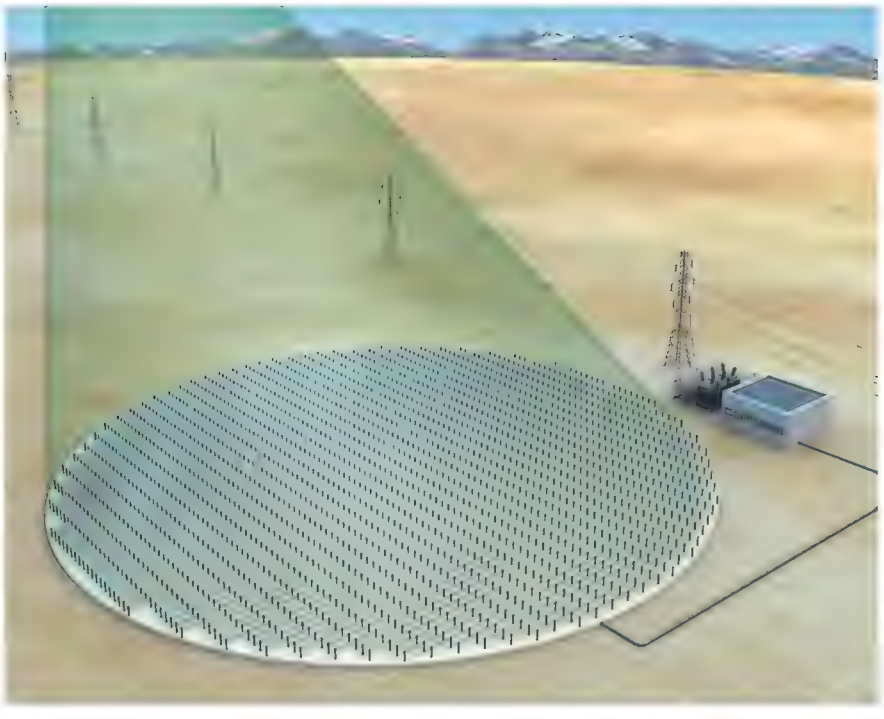
Grider, in the meantime, had also survived flight training, accumulating about 20 solo hours before being sent to the School of Aerial Fighting in Ayr, Scotland. There, he advanced from Farmans to French SPADs, and saw nine cadets die in crashes. He was at Ayr just 19 days when he was ordered to the front. "I'd like to stay here a while," he wrote, "but they kill off pilots too fast for any one to linger very long."

Assigned to the 85th Squadron under Canadian air ace Lieutenant Colonel William "Billy" Bishop, Grider flew bomber escort and patrols, helping to neutralize Germany's new Fokker D.VII. He downed four enemy airplanes before disappearing in a fog behind enemy lines in June 1918. His squadron learned later from a note dropped by a German pilot that Grider had been shot down in a dogfight and was buried somewhere in Armentieres, France. The airfield in Pine Bluff, Arkansas, is dedicated to him.

As for Shaw, after completing his training at Cranwell, learning on BE2cs and Airco DH9s, he was sent to the #1 School of Navigation and Bomb Dropping at Stonehenge. There he learned how to fly the giant Handley Page O-400 twin-engine bomber, and how to conduct night bombing missions. By the time he finished the six-week course and was assigned to 100 Squadron in France, it was the last week of October 1918. Within two weeks, the Armistice was signed and the guns fell silent. Eight months later, Shaw returned to the United States without ever having flown a combat mission. While surviving flight training was lucky in itself, his crash was even luckier: Being out of commission for eight weeks may have saved his life. Back home in Missouri, he married his sweetheart, Dorothy Price, and the two had a daughter, Janet—my mother. His good luck, it turns out, was mine too.

This Fokker D.VII was captured in northern France. The airplane was so effective that at war's end, Germany was required to surrender all of them. Below: Shaw (circled) kept this postcard of his classmates in Greenwich, England.





JOHN MACNEILL (2)

In a 1990s concept, solar cells in space (top), arranged like leaves on a stem – actually a tether that stabilizes the sunsat's orbit – feed a transmitter that beams microwaves to a receiver on Earth.

WE WANT TO BELIEVE. The latest report on a 40-year-old concept—satellites that could gather energy from the sun and supply it to the world as electricity—makes the technology seem reachable and even, eventually, affordable.

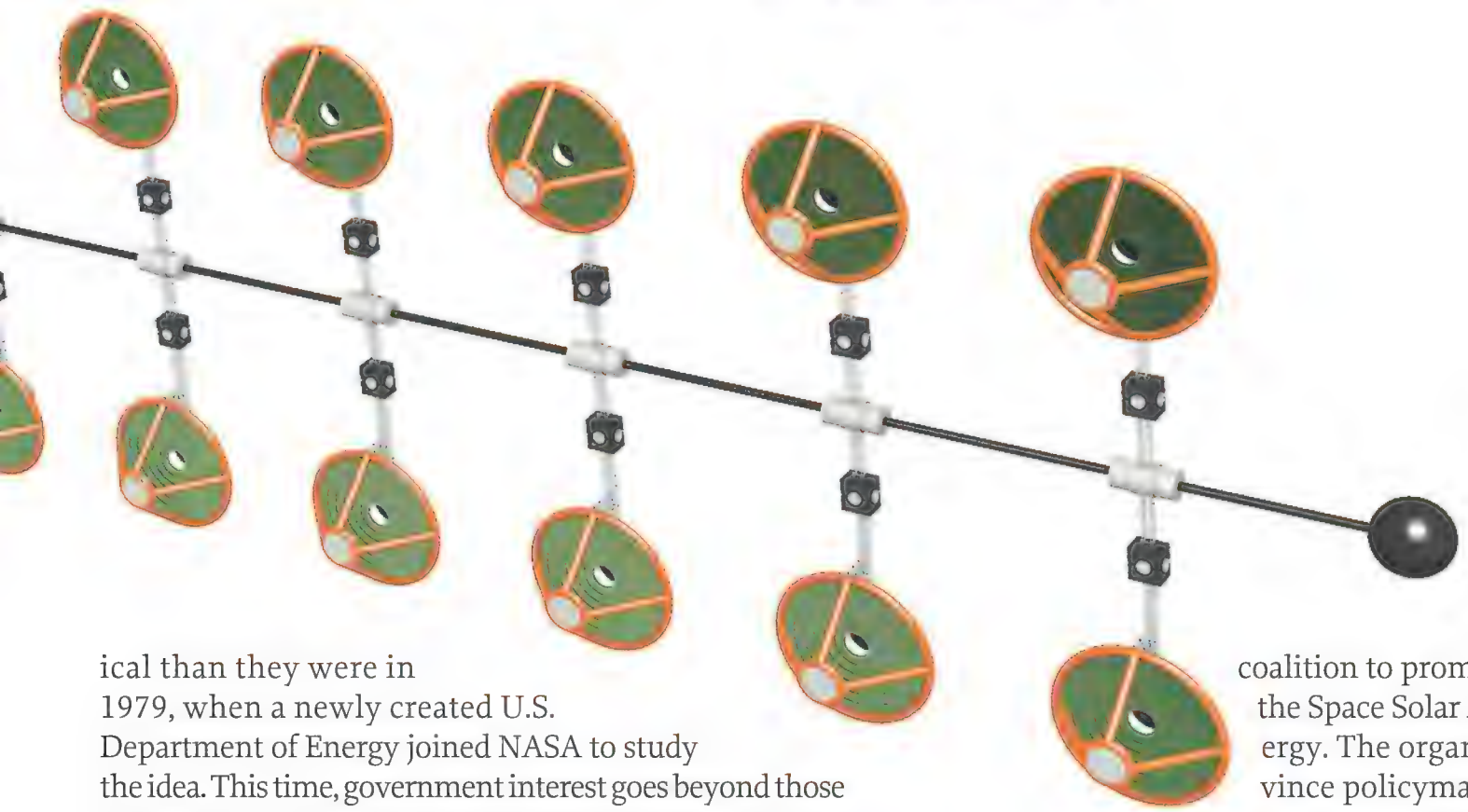
Here's the plan: Construct in Earth orbit, where the sun never sets, gigantic collectors (a 1979 proposal envisioned arrays six miles by three miles) that would beam solar energy to similarly huge receivers on Earth, which would convert it to electricity. In other words, hook the sun up to the grid.

Here's why it stalled the first time: According to a 1981 estimate by the National Research Council, it would have cost $3 trillion. Building and launching the enormous structures turned out to be so famously expensive that even today, advocates of space solar power struggle to overcome its reputation for outlandishness. Thirty years later, though, the idea is getting another look, for two reasons. Advances in almost all of the required technologies could dramatically reduce the size and cost of the system. And, maybe more importantly, circumstances on the planet—the cost of energy, the global impact of producing it, and worry about its supply—have grown even more crit-

WHERE THE SUN DOES SHINE

WILL SPACE SOLAR POWER EVER BE PRACTICAL?

BY LINDA SHINER



ical than they were in 1979, when a newly created U.S. Department of Energy joined NASA to study the idea. This time, government interest goes beyond those two agencies—the most recent report on the feasibility of sunsats, completed last October, was requested by the Department of Defense, through a little-known group of policy advisors called the National Security Space Office.

Why them? For one thing, supplying electricity to forward bases in Iraq and Afghanistan is hugely expensive—more than a dollar a kilowatt-hour. (The average cost Stateside last year was under nine cents a kilowatt-hour.) If some organization could deliver between five and 50 megawatts for less than a dollar a kilowatt-hour, the National Security Space Office says, the Pentagon could be an anchor customer.

That's just the kind of guaranteed business a space power system would need to become viable, according to experts involved in the study. At a press conference last October, the National Space Society, one of several space advocacy groups whose members contributed to the report, announced a new coalition to promote space solar power: the Space Solar Alliance for Future Energy. The organization hopes to convince policymakers that space power deserves government funding—at least to build a demonstrator—because of its potential to produce electricity cleanly, in vast amounts.

If the government could provide seed money, says John Mankins, "there are lots of companies around the world" that could manufacture the components of a system much smaller and smarter than the behemoth envisioned in the 1970s. Mankins, the president of the Space Power Association, is one of the world's leading experts on the concept. Formerly a research-and-technology manager in NASA's space exploration office, he ran several space solar power studies between 1995 and 2003 that took stock of current capabilities and calculated the investment required to get to a working system.

Five years later, advances in several technologies, starting with photovoltaics, have made him hopeful. The Defense Advanced Research Projects Agency is now funding research with

NASA

COURTESY KYOTO UNIVERSITY RADIO SCIENCE CENTER FOR SPACE AND ATMOSPHERE (KURASC)

Light and microwaves have powered small aircraft at Alabama's Marshall Space Flight Center in 2003 (left) and in Japan in 1992 (right). Such wireless transmission will be required of space power.

the goal of demonstrating a solar cell that can convert 50 percent of the sunlight striking it to electricity. Under the DARPA program, a consortium led by the DuPont corporation and the University of Delaware has achieved 42.8 percent efficiency by using a "rainbow" technique to separate sunlight into its constituent wavelengths and guide them to photovoltaic materials sensitive to those ranges of energies.

The sunsat studies of the 1970s assumed efficiency of nine or 10 percent, says Mankins. If that could be brought to 50 percent, the total area of the space-based solar collectors could be reduced by 80 percent while still producing the same amount of power. In addition, says Mankins, "all the power cabling, all the thermal management and attitude control, the gyros—all of the stuff that went with the 80 percent you just got rid of—it goes away."

Wireless power transmission, the means by which the collected solar energy is delivered to the ground, has also progressed. Even 30 years ago, the basic technique was known to work. In fact, the distance record for microwave beaming was set in 1975 at the Jet Propulsion Laboratory's Goldstone facility near Barstow, California. Experimenters transmitted 34 kilowatts of power to a receiver almost a mile away, and more than 82 percent of it was converted to electricity. In 1993, researchers from Kobe University in Japan and Texas A&M University used a transmitter and receiver launched on a sounding rocket to demonstrate microwave transmission in space for the first time.

Techniques for building sunsats have not come as far. The 1979 study envisioned hundreds of astronaut spacewalkers toiling for decades. Robotic assembly would be more practical. But despite the sometimes photogenic robots creeping around NASA centers and university laboratories, the only construction project in space, the International Space Station, is still being assembled by astronauts.

Not that the field of space robotics isn't advancing. Robots that may someday build large structures in orbit might look like Roby Space Junior, a spiderbot created by an institute at the Vienna University of Technology (famous in Europe for creating a tiny robot soccer team). The four-inch-square Roby was designed to crawl on a vast web-like structure called a Furoshiki spacecraft, a lightweight mesh that could form the platform for large antennas, sails—or solar collectors. In 2006, the European and Japanese space agencies joined forces to launch a 65- by 130-foot Furoshiki web and three spiderbots on a sounding rocket that produced a few minutes of weightlessness. The net deployed, and the robots crawled on it for a few seconds.

The experiment seems typical of recent work on space solar power: ingenious, but a long way from tackling the huge challenges that space power systems face. The Japanese and European space agencies are funding research, but as of today, there is no credible project to build systems that will demonstrate all the necessary elements working together.

If he had the $850 million annual budget he once managed at NASA, Mankins would spend a big chunk of it to develop modular systems, a building-block approach to the assembly of large space structures. He likens it to lots of small, networked computers replacing a few big, powerful supercomputers. "If you think of trying to build a single mainframe with 1960s technology that had the processing capabilities of the Internet, it would be the size of Manhattan. But think of the Internet: You

have these millions of individual computers working cooperatively over a network."

The "modular" in modular systems represents tens of thousands of identical, mass-produced (and therefore cheap) parts. Each part, because of advances in solid-state electronics, could serve as both collector and transmitter. "Think of an Iridium satellite," says Mankins. The Iridium network uses 66 satellites to provide wireless communication worldwide. "It has integrated into [a satellite] the size of a VW Bug power generation, intelligence, attitude control, and microwave phased arrays." Now imagine that satellite flattened into a tiny hexagon, one of 10,000 collecting-transmitting hexagons on a single satellite.

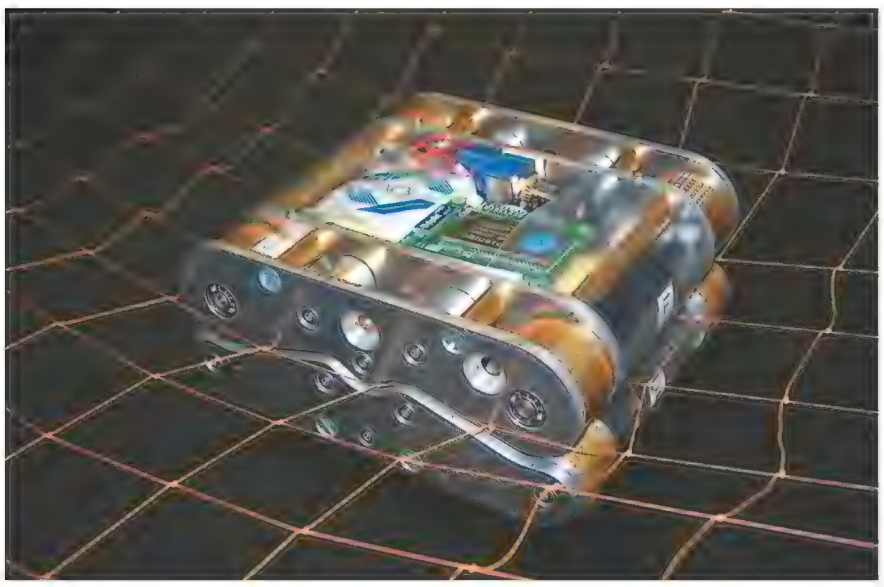
That's the kind of innovation Mankins wants to see funded. But to which federal agency should he apply? Neither NASA nor the Department of Energy has ever shown much interest in nurturing sunsat technology.

If the government put money into space solar power, would taxpayers get a return on their investment? Molly Macauley, an economist with Resources for the Future, a Washington, D.C. energy and environment think tank, has studied the ability of sunsats to compete with other renewable energy technologies. It's a hard case to make, she says. "Advocates of space solar power fail to acknowledge that technological change and innovation are happening in other types of renewable energy—ground-based solar power, concentrated solar power, wind, geothermal energy. The ability to compete on a cents-per-kilowatt-hour basis is going to get more difficult, not less difficult."

Perhaps the biggest hurdle facing space solar power is public concern about how low-level microwave beams will affect animals and humans. Never mind that the fear remains unfounded. Because of the widespread use of microwaves for communication, the Federal Communications Commission has established a safety standard for human exposure. In all proposed space power systems, the expected power density at the edges of the receiving antenna, where people are most likely to be affected, meets the standard. But explaining this to the public, which hears "microwave" and thinks "oven," might require a large and costly education campaign. Another worry, that microwave beams could scramble a passing airliner's avionics or harm passengers, could be addressed by restricting the airspace around the beams, just as the Federal Aviation Administration restricts the airspace over nuclear power plants. Space power advocates may find it instructive to study the political struggles of the nuclear power industry.

At the October press conference, speakers pointed out that the inevitable pursuit of higher standards of living will increase competition for energy, and that by mid-century, the global population will have increased from six to nine billion. It's not much of a reach to apocalyptic visions of clashes over diminishing fuel.

Can the sunsat believers make the case that space solar power is one way to help meet the growing demand for clean, inexhaustible energy? And if so, will they find a branch of the government that can support and coordinate the necessary research? We want to believe.



IHRT/VIENNA UNIVERSITY OF TECHNOLOGY

Sunsats could be assembled by spiderbots, like the four-inch-square Roby Space Junior. Or they could be inflatable structures, like the antenna unfurled on a 1996 space shuttle mission (below).

NASA (2)

Resto

Arrow Sport | Swen Swanson's Sportster

AS FAR BACK AS Todd Rhode can remember, there was an airplane in the garage. His parents, Herbert "Dusty" and Nelda Rhode, had trailered the fixer-upper Arrow Sport biplane home to Florida two years before Todd was born.

In 1926, designer Swen Swanson produced a small biplane for the Arrow Aircraft and Motor Corporation of Havelock, Nebraska. It featured side-by-side seating, a wide single-strut landing gear that made landing and taxiing in a crosswind more stable, differential ailerons that reduced yawing in turns, and a horizontal stabilizer that the pilot could adjust from the cockpit to trim the tail to the desired control pressure. Most daring was a pair of fully cantilevered wings that were supported by internal spars.

Seeing a market for side-by-side seating in flight instruction, Arrow began production of the Sport. The company retained the wide landing gear and added bungee shock absorbers at a time when many airplanes had rigid gear that relied only on the tires to absorb shocks. Arrow settled on a 60-horsepower Le Blond five-cylinder radial engine and, because buyers were used to wings braced by wires and struts, offered a set of reassuring but unnecessary N-struts between the wings.

Arrow Sport serial number 343, registered as NC9327, rolled off the Havelock assembly line on April 19, 1929, one of about a hundred Arrow Sport A2-60s built over a five-year span. (NC9325, which hangs in the National Air and Space Museum's Steven F. Udvar-Hazy Center, had come off the line just days earlier.) Eight years later, it suffered a mishap while landing in Cumberland, Rhode Island. The wreck passed through several hands until Dusty Rhode bought it in 1960. "I may have been pre-destined for a life in aviation," Rhode says, "and maybe the Arrow Sport too. I was born the day Lindbergh took off for Paris, and the Arrow's first home was Roosevelt Field—Lindbergh's departure point." But his three children and his job as a flight engineer—which would eventually result in logging 35,000 flight hours with National and Pan American airlines—kept him too busy to restore the Arrow. It remained stored until 2003. At that point, Todd was startled to learn that his father had traded it—for another Arrow Sport, NC804M—which had been put back together by restorer Dean Tilton.

This would never do. "When I was small, my friends and I spent hours in the cockpit, 'flying' our Arrow," Todd says. "I'm not a pilot, but that airplane has carried me all over the world in my imagination. I was deeply troubled by the idea of letting it go."

He persuaded his father and Tilton to strike a new deal. NC9327 would remain in the Rhode family, and they would pay Tilton to restore it. The airplane was delivered to Tilton's hangar in Lakeland, Florida, where he began work on the wings.

"Arrow used two spars in each wing," Tilton says. "They run from tip to tip—25 feet. The spars on this airplane were damaged in the 1937 accident, but I had parts from the earlier project and I was able to build up a good set for each wing."

The spars are joined by gothically curved wood ribs that define the Eiffel 385 airfoil (designed by Alexandre-Gustave Eiffel of Tower fame). Most of the originals were not airworthy, but Tilton was able to use them as patterns.

COURTESY HW RHODE

ALL PHOTOS: PETRA MARSHALL

Decades after the Rhodes towed home Arrow NC9327 behind their 1955 Chevrolet (left), restorer Dean Tilton (above, at right, with Todd Rhode) cleaned up the steel fuselage and got the Arrow back in shape.

r a t i o n

Tilton made the Arrow's mahogany instrument panel (left). The restored airplane now resides at a private strip in Dade City, Florida.

Because the top and bottom wings have different chords (the distance between the leading and trailing edges) and both taper, Tilton had to build several rib jigs. Each jig could produce only two ribs; one left, one right. He and his wife Christine stitched and weatherproofed many yards of new Stits polyfiber covering. Christine found that the builder of the aluminum seat had etched his signature in it, so she restored rather than replaced the seat and reconditioned the original horsehair cushion.

Tilton bead-blasted light rust and pitting off the steel-tube fuselage, had the tubes tested for internal corrosion, and moved on to the engine. Parts for Le Blonds are scarce, but the engine is simple, so a local machine shop made new valve guides and a few other parts from scratch.

Tilton, Todd Rhode, and Todd's wife Petra (whose grandfather flew with Manfred von Richthofen in World War I) worked together for two years, making parts, sanding, assembling, and covering the wings and fuselage with fabric. Early in 2007, the fully restored and painted Arrow was rolled out into the sun. The Rhodes watched Tilton settle into the cockpit. For the first time in his life, Todd swung the propeller. The little radial engine emitted puffs of white smoke and settled into a steady idle.

A month later, after minor adjustments had been made and the family had reunited for the occasion, the Arrow got airborne, for the first time in 70 years, powered by a 78-year-old engine and two generations of dreams.

KEN SCOTT

DANE PENLAND

NC9327's sibling now hangs in the Steven F. Udvar-Hazy Center. A British owner changed its first registration number, NC9325, to one that proudly states its name (with liberal use of poetic/spelling license).

What would it be like to approach a tumbling asteroid? Orion would match its slow rotation, then fly in formation – no "landing" necessary.

The MILLION MILE *Mission*

A SMALL BAND OF BELIEVERS URGES NASA TO TAKE ITS NEXT STEP – TO AN ASTEROID.

>> BY MICHAEL KLESIUS

>> ILLUSTRATIONS BY PAUL DiMARE

IT WAS ANOTHER BRILLIANTLY SUNNY DAY for NASA astronaut Tom Jones. In orbit on his fourth space shuttle mission in February 2001, Jones was outside the International Space Station, installing a new laboratory module. He remembers the moment with great clarity: Gerhard Thiele, another astronaut, called from the ground to relay the news that the robotic NEAR Shoemaker probe had just made the first-ever landing on an asteroid, 433 Eros.

"There I was, turning bolts on the ISS," says Jones. "I was thinking: What a cool job this is. But how much cooler would it be if I were doing this on an asteroid!"

The idea that astronauts might visit an asteroid and explore it up close had long intrigued him. Today, Jones is more convinced than ever that it would be a grand and worthwhile journey. "The asteroids," he says, "are begging for a visit."

By "the asteroids" he doesn't mean one of the rocks circling out in the main belt between Mars and Jupiter, but something a lot closer to home: An Earth-crosser, or NEO (near-Earth object). A rogue.

Jones is part of an unofficial group of NASA actives and alums who have been studying, mostly on their own time, the particulars—engineering requirements, mission trajectories, scientific payoffs, and costs—of a human trip to an asteroid. Like the Mars Underground, a larger group of enthusiasts who for the past 20-plus years have been pushing for a voyage to Mars, the asteroid agitators are trying to build support for a mission. The two groups are far from mutually exclusive: Plenty of Mars Un-

1. The Orion crew vehicle and Earth departure stage launch separately on Ares rockets, then join up in orbit.

2. The departure stage fires to send Orion on a weeks-long journey to its destination.

"I THINK IT'S A VALUABLE IDEA. It would help validate the Constellation hardware within a meaningful time frame. Basically, it takes us farther out into space, and that's good. Sort of like Columbus getting out there and saying, 'There aren't dragons out here after all.' " – ROBERT ZUBRIN, AEROSPACE ENGINEER

dergrounders share the desire to see Constellation, NASA's human exploration program, send astronauts rock-hopping first.

The operational lessons learned from such an expedition would be crucial. "There's no way a Mars program could take shape without a crewed mission to an asteroid," says Jones. Aerospace engineer Robert Zubrin, who, as head of the international advocacy group the Mars Society, is one of the leading proponents of an expedition to the Red Planet, likes the logic of a shakedown flight to an asteroid. "I think it's a valuable idea. It would help validate the Constellation hardware within a meaningful time frame," he says. "Basically, it takes us farther out into space, and that's good. Sort of like Columbus getting out there and saying, 'There aren't dragons out here after all.' "

Constellation's primary destinations are the moon and Mars, but the asteroid hopefuls are lobbying to insert a third stop in the itinerary. For the record, NASA has no plans to send astronauts to a near-Earth object, and agency officials describe it as highly improbable given current budgets.

The Asteroid Underground is unfazed. According to Jones, "When you talk to an audience of taxpayers, they see the stepping stones: moon, asteroid, Mars."

The idea of a mission to an asteroid is not new. In 1966, Eugene Smith, an engineer with Northrop Space Laboratories, conducted a study for NASA on the use of Apollo hardware, including the giant Saturn V rocket, to carry six astronauts on a flyby of Eros. The trip would have been scheduled for 1975, when the asteroid came within 13 million miles of Earth, more than 50 times the distance to the moon. The round trip would have been 500 days.

More recently, NEOs came to public attention in July 1994, when the comet Shoemaker-Levy 9 broke up and the pieces slammed into Jupiter, the largest packing a wallop equivalent to 400,000 times the power of the largest U.S. nuclear bomb ever exploded. Anyone who read a newspaper that summer imagined the same thing happening to Earth, and within two years an international organization called the Spaceguard Foundation was established to coordinate the tracking of asteroids and comets that might collide with the home planet.

Shoemaker-Levy got more people inside and outside NASA thinking seriously about the danger of NEOs. In October 2001, astronaut Ed Lu and astrophysicist Piet Hut convened a one-day workshop in Houston with about 20 asteroid and propulsion experts to discuss the possibility of deflecting an incoming NEO. Out of that meeting the B612 Foundation was formed,

3. Orion spends up to two weeks at the asteroid before returning to Earth.

A bare-bones asteroid mission could use hardware NASA already has in the works: Ares rockets (left) to leave Earth, and a departure stage (middle) to send Orion and crew on their way.

named for the space rock on which author Antoine de St. Exupéry's Little Prince lived. The stated goal of the organization, now headed by Apollo veteran Rusty Schweickart, is to significantly alter the orbit of an asteroid in a controlled manner by 2015, just to show that it can be done.

Not by astronauts, though.

"I'm an old astronaut, so I'm totally for manned flights to an asteroid," says Schweickart, who was Apollo 9's lunar module pilot. "But in terms of deflecting one, robotic missions are completely adequate and far more cost-effective."

The B612 Foundation proposes a rendezvous with a space rock for weeks or months, during which the robot spacecraft would act as a "gravity tractor," using its own minuscule gravitational pull to tug the asteroid onto a new course. While B612 spread its message, Ed Lu went on to spend six months aboard the International Space Station. Three months after his return to Earth, in January 2004, the Bush administration announced its Vision for Space Exploration, an ambitious call to send astronauts beyond Earth orbit for the first time since 1972. While NASA set up Constellation and began focusing on the lunar return, targeted for 2020, Lu and the Asteroid Underground quietly pondered other possibilities.

"When NASA unveiled the concepts of the Ares I and V launch vehicles and [the] Orion [crew capsule]," remembers Lu, "I started wondering, 'Hey, we have these rockets at our disposal. What else can we do?' "

By the summer of 2006, Lu, Tom Jones, and Dave Korsmeyer, an engineer at NASA's Ames Research Center who specializes in celestial mechanics, were conferring regularly with more than a dozen colleagues around the country, asking about the capabilities of Constellation and writing papers. NASA agreed to fund a feasibility study through its Advanced Projects Office that would examine how to use the Orion and Ares hardware to send people to a near-Earth asteroid. Korsmeyer managed the group. After many phone calls and e-mails among the 17 members of the study team, the first meeting took place at the Johnson Space Center in Houston in August 2006. Subsequent gatherings, about one per month, were convened at various NASA centers around the country. By the end of the year, the group had come to the conclusion that NASA's new hardware could in fact carry humans to a NEO.

"The first part of this study was to determine if we could make it to an asteroid with no modifications whatsoever to Orion and the launch vehicle," says Korsmeyer. "But that would be pretty hard and hairy."

The weight of the crew, plus all the water, food, oxygen, and other supplies needed for a long voyage, posed a huge constraint. So the study team reduced the crew from four people (the baseline for a lunar mission) to three or even two, which freed up room for supplies. The good news is that a six-month asteroid mission wouldn't require advanced systems for recycling water and air; Orion's should be good enough.

The group also wrestled with the problem of communicating with a spacecraft more than two million miles from home. "At even a near-Earth asteroid, you're 10 voice-seconds away," says Korsmeyer. "You're not really conversing with Earth at that point. The whole nature of the interaction becomes like the old ship-to-shore communications, a fancy telegraph, a voicemail. Not in real-time."

An asteroid-bound crew would therefore need to "bring mission control on board," says Korsmeyer, in the form of highly automated decision-making software. "When something bad happens, which tends to happen quickly, the crew and systems will have to manage it on their own. This is something humanity hasn't done yet. But that makes it the best of all possible testing grounds for Mars, which, without an asteroid mission, will be like jumping into the deep end without practicing in the shallow end." In comparison, "the moon is like the baby pool. I don't mean to minimize that—Apollo 13 showed us you can drown there too." But, he says, an asteroid "would really be someplace fabulously new. You're talking 2.5 million miles, more than 10 times the distance between Earth and the moon. You'd be so far away you could cover up Earth with your finger. It would be no more than a beautiful, pale blue star."

The 2006 NASA study didn't go into detail about what astronauts would do once they reached an asteroid. But results from Japan's robotic Hayabusa mission, which in 2005 investigated the near-Earth asteroid 25143 Itokawa up close, have led to some intriguing speculations.

"Itokawa was one of the most heavily researched asteroids—radar, visible, infrared," says Paul Abell, a scientist on contract with NASA from the Planetary Science Institute who participated in the Advanced Projects Office study. "Many countries and collaborators had studied it. But when we got there with

Hayabusa we were surprised by what we saw."

It turned out to be a rubble pile loosely held together by its own gravity. "It's a sandbox," Abell says, "about 40 percent porous. Lots of empty space, like you have in a jar full of marbles. That was a really profound discovery."

The first asteroid to be explored by humans might look a lot like Itokawa. While scientists are reluctant to name a specific target when the mission hasn't even been approved, two candidates tend to crop up on lists of NEOs that would be reachable in the next two decades. A tiny one called 1991 VG—just 40 by 14 feet, or about one-seventh the size of Itokawa—comes around in the year 2017, but is probably too small to be of interest. A more likely candidate, 1999 AO10, is the size of a football field. It could be reached in 2025, long after Orion starts flying. Both missions would require a round trip of 150 days.

"We really don't have a 'best one,' " says Abell. "It's far too early in the time line to select a target." Besides, scientists find new asteroids all the time. "Hopefully we will have many more [choices], and get to know them a little better than we do now."

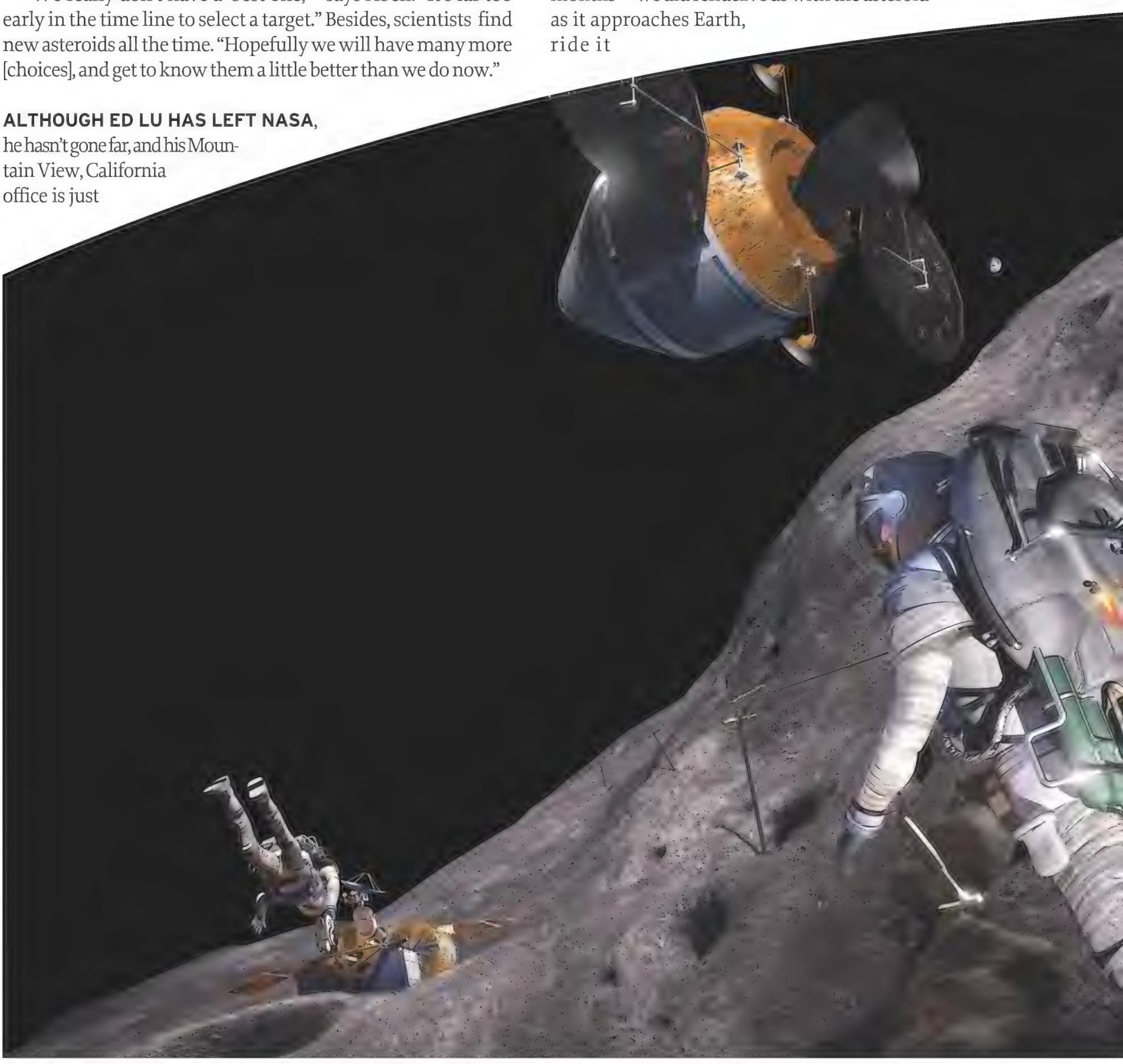
ALTHOUGH ED LU HAS LEFT NASA, he hasn't gone far, and his Mountain View, California office is just down the road from Korsmeyer's. Lu took a job last year with an advanced projects group at the headquarters of Google, where the former astronaut is dreaming up technologies that will go beyond Google Maps and Google Earth. He thinks of it as Google's version of the Lockheed Skunk Works.

Lu says there are two basic ways to reach a NEO. An optimal target would have an orbit similar in breadth to Earth's, but inclined, so that it would cross the plane of Earth's orbit at a point not far away. Such an object would come around every six months.

Orion would fly out to meet the asteroid at its first plane crossing, stay with it for half a year, then come home when the asteroid crosses the plane again on the opposite side of the sun.

"You hop on," says Lu, "and hop off six months later." The payoff: less fuel required.

The other option—a shorter mission of up to, say, four months—would rendezvous with the asteroid as it approaches Earth, ride it



home, then hop off. Or, hop on as it passes Earth, ride it for a few weeks, and hop off in deep space, requiring a return trip of several weeks to a couple months. This type of mission demands more fuel, but would open the field to a greater number of target asteroids.

None of these missions requires more time in space than the six months astronauts typically spend on the space station. A Mars round trip requires three years. Lu's own return after six months of weightlessness was easy, he says. Having spent two hours on aerobic and strength training every day in orbit—"and we did it religiously"—he was able to stand

An asteroid's low gravity would pose a challenge: how to work on the surface without bouncing off into space.

GIVEN THAT ASTRONAUTS WOULD stay anywhere from five days to two weeks at an asteroid, there's no shortage of work to be done there. "Tons of science," says the Planetary Science Institute's Paul Abell, who was on NASA's Phase I study team in 2006. "The first objective would be to return samples. These asteroids are leftover material that was never incorporated into the planets. They're a time capsule going back 4.6 billion years." He adds that we might find volatile and organic compounds we never knew about, or those we do, such as water.

How close Orion would approach depends on the asteroid's size and gravitational field. The ship would have to match the rock's rotation, and would probably stay a mile or two away while the crew uses remote sensing instruments to study the surface. It would draw closer for hands-on exploration by the astronauts, possibly to within hundreds or even tens of yards. But actually "landing" the ship on the surface may in the end prove too risky.

And unnecessary. Detailed ideas for how astronauts could conduct asteroid "walks" await a not-yet-approved Phase II study by the NASA team. But theoretically, they might approach with tethers or jet packs. Engineers will have to come up with ways for astronauts to gain purchase on an asteroid – perhaps with small anchors shot into the

We're here! Now what?

rock or rubble. Once anchored, they could conduct robotic operations, collect samples, or deploy rigs for extracting resources. A robotic arm probably wouldn't fit on Orion, but all options are still on the table.

The astronauts could also probe the asteroid's inner structure. "The CEV [crew exploration vehicle] would have a tunable Ku-band radar on board, so astronauts could do sort of a CAT scan of the asteroid," says Rob Landis, another member of the NASA study team who works closely with Abell.

Carlton Allen, curator of astro-materials at NASA's Johnson Space Center in Houston, looks forward to the scientific payoff. "Some meteorites, especially carbonaceous chondrites, contain complex organic molecules, including amino acids, the fundamental building blocks of life," he says. "Some NEOs may be related to meteorites already in our labs, and studying them will help us bridge the gap between meteorites and other worlds."

Finally, with an eye toward saving Earth from a space rock that could someday threaten the planet, astronauts might try giving a nudge to the asteroid to see how easily they can divert it. Allen envisions "a high-kinetic-impulse experiment" that would alter the asteroid's path slightly, with the change in direction measured by seismometers. That way, some of the hefty sums spent on an asteroid expedition might buy a bit of planetary protection.

Far from home: Sending people a few million miles from Earth would push engineers to develop technology and life support systems for the much longer journey to Mars.

up on the Kazakh plain immediately after landing there in a Russian Soyuz capsule. "I was 70 percent normal within a few days, and 90 percent within three weeks," he says.

In other words, one of the big unknowns about a Mars trip—how the human body will react to three years of weightlessness—is no concern at all for an asteroid mission. And once they reach their destination, the astronauts won't have to adapt to one-third Earth gravity, as they would on the surface of Mars. Amid all the discussion of "hopping on and off," Lu makes a key point. "People get the misconception that we'll land on an asteroid," he says. "We won't. It's almost zero-G. You're not going to walk on that surface." Working around an asteroid would in some ways be like floating around the space station, which is also the size of a football field. Astronauts would likely perform asteroid "walks" using jet backpacks or tethers, possibly firing small anchors into the surface for leverage.

What about the cramped nature of a six-month voyage inside Orion, with a habitable volume only one-fifth that of the space shuttle? Lu shrugs it off. "If I knew I was going out to an asteroid and back, I'd live in something half that size. You ask around the Astronaut Office who wants to go. You'll have a line out the door."

That comes as no surprise to Bob Farquhar, a former mission designer for such robotic spacecraft as NEAR Shoemaker, Messenger to Mercury, and New Horizons to Pluto. He's now a fellow at the National Air and Space Museum. "I don't doubt you'd have guys volunteering to climb inside Orion for six months," he says. "You could get astronauts who'd volunteer for a one-way mission to Mars. But that's not the way we do it."

In the Asteroid Underground, Farquhar is something of an elder statesman and is known for his outspokenness. Having taken part in a recent feasibility study for the International Academy of Astronautics that looked at different options for moving beyond Earth orbit, he doesn't like the idea of making do with existing Constellation hardware for a stripped-down asteroid mission. "You'd need a transfer vehicle," he says. "Something big and roomy. And you don't want it in low Earth orbit all the time." Instead, he would park an interplanetary, or inter-asteroidal, transfer vehicle at the L2 libration point, about a million miles outside Earth's orbit, where the gravitational pulls of the sun and Earth are balanced. The transfer vehicle would pick up the crew members in Earth orbit, take them to an asteroid (or, someday, Mars), and then, at journey's end, return them to Earth orbit.

However the missions are designed, astronauts who travel to an asteroid will spend months outside Earth's magnetic field, which shields space station crews from harmful space radiation. An asteroid-bound ship would need heavy shielding: perhaps a water or hydrogen jacket, or thick plastic composites. Another unknown, and another technology to develop.

Despite such challenges, the Asteroid Underground has won converts, in part due to a lack of enthusiasm among many in the space advocacy community for NASA's current plans to return to the moon. Farquhar has been among the most vocal critics. "We need to reexamine this whole lunar thing," he says. "I think you could skip the lunar landing and lunar bases. They'll eat up NASA's budget for the next 50 or 60 years." In fact, the price tag for an asteroid mission would almost certainly be less than the cost of a lunar landing.

Farquhar was one of 50 thinkers who attended an invitation-only workshop at Stanford University last February, sponsored by the Planetary Society and titled "Examining the Vision: Balancing Science and Exploration." The group included scientists, aerospace executives, space advocates, NASA staff, and former astronauts. Press reports prior to the meeting made it sound like the Asteroid Underground planned an insurrection against NASA's lunar program. That led agency administrator Mike Griffin, who has fought to win support in Congress for Constellation, to lash out against those who would push destinations other than NASA's approved next step, the moon. The controversy may explain why, instead of arguing strongly for an asteroid mission, the statement that came out of the workshop merely called for sustained human exploration to Mars and beyond, which would be done via the moon and "other interme-

WHAT ABOUT THE CRAMPED six-month voyage inside Orion, with a habitable volume one-fifth that of the space shuttle? Ed Lu shrugs it off. "If I knew I was going to an asteroid and back, I'd live in something half that size. Ask around the Astronaut Office who wants to go. You'll have a line out the door."

diate destinations." The word "asteroids" was never mentioned.

Farquhar calls the statement "wishy-washy" and says the meeting was co-opted by NASA attendees. "The Stanford conference didn't accomplish what [the asteroid advocates] had hoped, which was to take another look at the whole program. The organizers were trying to have an ecumenical experience, inviting people from throughout the industry. There turned out to be more of the faithful than the dissidents. I thought it was a flop."

For the time being, it seems, the Asteroid Underground has suffered a setback. But the prospect of political change (a new president not wedded to the moon plan), and not just in the United States, gives asteroid mission advocates hope that their fortunes will soon improve. "We might wind up around 2020 with the Chinese about to set foot on the moon, possibly with the Russians," says Jones. "But we'll have something else in our back pocket—on our way to an asteroid, we could wave at them down on the lunar surface and say, 'We did that 50 years ago.' "

Dave Korsmeyer has been optimistic about NASA's interest in asteroids ever since he briefed Constellation manager Jeff Hanley on his study group's findings in February 2007. "Hanley said, 'This is great!' He said the best thing for us to know is that this [Constellation] architecture goes to more than one place instead of just 'round the block.

"Every month since, we've been giving a briefing to someone, and not because we're pushing it. They're asking for it." A more detailed study, he says, may be forthcoming.

Rob Landis, a member of the study group with experience in mission control, says, "Apollo 8 was never intended to go to the moon. But NASA said, 'What if we go anyway?' That was a huge, quantum leap. I'd say that an asteroid mission is the Apollo 8 of the next generation—before jumping off to Mars, before dipping our toes deeper in that cosmic ocean."

Sightings

PICTURES WORTH A SECOND LOOK

WHO KNEW THE POWER OF A PATCH could launch a thousand jets? In the summer of 1961, the 79th TFS Tigers of the U.S. Air Force, based at Woodbridge, Suffolk, in England, invited No. 74 Squadron of the Royal Air Force and France's 1/12 Squadron to a "meet," or joint air exercise. Three countries, one mascot: A tiger on each unit's patch served as a shared symbol of strength, speed, and hunting prowess.

Word of the Tiger Meet spread. Each year more NATO cats came prowling. Today, crews cloak their jets in schemes that "offer rich pickings for the photographer," says Kevin Jackson, a British shooter who snuck up on a French Super Étendard (below left) in "snow tiger" livery last year in host country Norway. Terrain there offered a cool backdrop (bottom) as a Norwegian F-16 led two Turkish ones, a Spanish F/A-18, and a French Mirage 2000. France, which hosts this June, also welcomed cat squadrons in 2003, among them a German Tornado (opposite, bottom). And helicopters are invited, such as the Czech Mi-24 Hind (below right) that came to Germany in 2004. "To an outsider, the Tiger Meet looks like a huge party," says Jackson. "It is far more. The meet could never survive unless [it] provided solid training in the form of realistic flying scenarios." It has also exported cat scratch fever to non-NATO countries like Brazil, where an F-5E (opposite, top) sported its stripes above Rio de Janeiro.

K. JACKSON/P. GREENGRASS – WWW.TMOTA.COM

LT. COL. ULI METTERNICH, RET. – GAF/OFFICIAL PHOTOGRAPHER, NATO TIGER ASSOC. (NTA)

KATSUHIKO TOKUNAGA, DACT, INC.

LT. COL. ULI METTERNICH, RET. – GAF/OFFICIAL PHOTOGRAPHER, NATO TIGER ASSOC. (NTA)

Towering Achievement

A BACKDROP IN THOUSANDS of pictures taken each year at the Experimental Aircraft Association's week-long gathering in Oshkosh, Wisconsin, the Wittman Regional Airport air traffic control tower is one of the world's most recognizable. During EAA's AirVenture, held at Wittman every summer since 1970, the tower becomes the world's busiest. But wear and tear is taking a toll, and the old building is nearing its end.

"Structurally and mechanically, it's a nightmare," says airport director Peter Moll. "It's pretty much in the old, original condition. There's no elevator. In fact, when they built it, they didn't have cranes. It was all concrete block and brick that was hauled up on scaffolding and placed by hand."

Work began on the tower in 1962, after Miron Construction came in with the lowest bid: $161,125. Opened the following year, the 70-foot-tall building was located just west of Basler Flight Service, on the north end of the then-35-year-old airport, known at the time as Winnebago County Airport.

In 1968, the tower needed to be moved so that controllers could see Runway 18/36, which had moved south to its current location. The 900-ton building was gently hoisted onto special dollies and towed inches at a time by a six-wheel truck. The mile-long trip took two weeks. At its new home, a taller foundation was built. That elevated air traffic controllers an additional 15 feet, giving them a better view of the airport, which by then had grown from 75 acres to 300.

In 1999 after a structural analysis showed the need for renovations, and federal standards required installing an elevator, officials decided that building a new tower would be more practical and cost-efficient.

The new location, at the corner of Knapp Street and Waukau Avenue, has the benefit of being close to sewer and water lines, and, at 120 feet high, the tower will give controllers the best possible view of the four runways on the airport's 1,400 acres. The tower's bigger cab will house more controllers, a definite plus during the summer airshow, when at any given time 15 to 20 controllers are working (the rest of the year, two are on shift). There is also an expanded telecommunications room, a bigger equipment room for radio transmitters and voice and data recorders, and a natural-gas emergency generator that replaces one that ran on diesel fuel.

As for cost, the tower is coming in "right around $7 million," says Moll.

Though the tower won't be completed until early 2009, the airport hopes to have the tower help out during this year's fly-in, which runs from July 28 to August 3. By then, the new cab will be able to house some controllers and minimal equipment.

Once the new tower is fully operating, the old one will be torn down. Why not try to preserve it? It blocks the new tower's view of one of the taxiways. "By FAA standards," says Moll, " you can't have any structure blocking the view of any operational services, so it has to come down." With its demise, the old tower will have finally passed the baton, and airshow visitors next year will find they have a brand new backdrop for all those keepsake photos.

KELLY NELSON

When the Experimental Aircraft Association's airshow opens in Oshkosh, Wisconsin in July, the taller tower may be active. The snow will be long gone, and by 2009's event, so will the old tower.

JIM KOEPNICK

Don't Run Out of Money During Retirement

Get Your FREE "Must-Read" Guide

What's your retirement going to be like? Will you be able to enjoy the "good life" and peace of mind, or spend your time worrying about making ends meet?

If you have $500,000 or more in investments, it's easy to believe that your retirement will be comfortable. Yet many investors, even financially successful ones, often make faulty assumptions about how much money they'll actually need.

Planning for a secure retirement takes expertise, not guesswork. *The 15-Minute Retirement Plan: How to Avoid Running Out of Money When You Need It Most*, written by the research staff at Fisher Investments, is loaded with practical information you can use to help meet your personal financial goals. For example:

- The truth about how long your nest egg can last. (It's worth requesting your free guide for this information alone!)
- Why it is vital to prepare for a long retirement
- How inflation can impact your retirement plan
- How much of an inheritance you'll be able to leave your heirs… and much more!

Benefit from this FREE Retirement Guide

Take advantage of this unique opportunity to benefit from the research of Fisher Investments. This valuable information can help you learn how to set sensible and achievable retirement goals. We are making this guide available to you because it serves as an introduction to our unique investing philosophy. You won't get these insights from anywhere else; they are absolutely free from Fisher Investments.

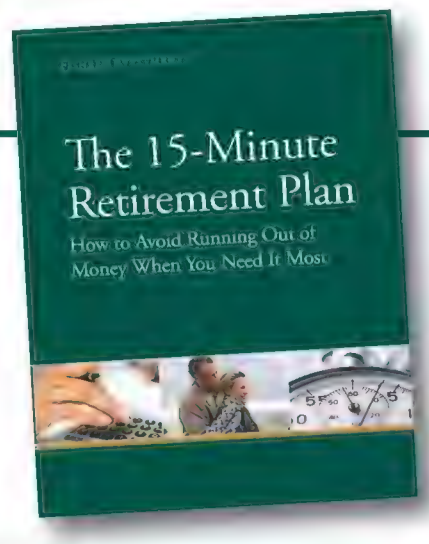
About Fisher Investments

Fisher Investments manages over $45 billion* in assets for financially successful individuals and institutional investors. For over two decades, and through bull and bear markets, Fisher Investments has used its proprietary research to manage the money of prudent investors with portfolios greater than $500,000.

I want to help put you on the right track for a secure retirement. *The 15-Minute Retirement Plan* contains valuable information you can use to help attain one of life's most important assets: peace of mind. Even if you have an investment plan in place right now, it still makes sense to request your free report. You never know when the insights you'll find may prove tremendously useful!

Please call now for this special offer. There's no charge and no obligation of any kind.

Ken Fisher
- Chairman and CEO, Fisher Investments
- *Forbes* "Portfolio Strategy" Columnist for 23 years
- Author of the 2007 *New York Times* Bestseller *The Only Three Questions That Count*



Please hurry! This offer contains time-sensitive information.

Call Today for Your FREE Guide!

1-800-695-5929 Ext. 5602

FISHER INVESTMENTS™

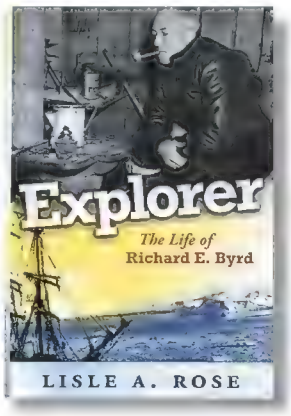
INVEST ASSURED

©2008 Fisher Investments. 13100 Skyline Blvd. Woodside, CA 94062-4547.
Investments in securities involve the risk of loss. *As of 12/31/2007.

Ice Man

Naval aviator Richard E. Byrd was driven to explore the desolate frozen seas at the top and bottom of the world.

COURTESY BYRD POLAR RESEARCH CENTER ARCHIVES, THE OHIO STATE UNIVERSITY, COLUMBUS



In August 1925, Richard Byrd was part of a U.S. Navy expedition that set up a base camp in Etah, Greenland (left). From Etah, the team sought – unsuccessfully – to fly over the north polar sea in Loening biplane amphibians.

Explorer: The Life of Richard E. Byrd

by Lisle A. Rose. University of Missouri Press, 2007. 544 pp., $34.95.

IN THIS THOROUGHLY researched, balanced, and vigorously argued biography of Arctic and Antarctic explorer Richard Evelyn Byrd, Lisle A. Rose, a polar veteran and author of a series of books on sea power, separates the man from the myth, the adulation, and the occasional bitter criticism that have attended him.

Byrd, who was from a distinguished Virginia family, traveled around the world as an adolescent, attended military school, and won appointment to the U.S. Naval Academy. As a junior officer, he risked his life on two occasions to save sailors who otherwise would have drowned. His impulsive athleticism, however, left him with permanent injuries; with little prospect of reaching high command, he retired on disability in 1916.

His second act began with the U.S. entry into the First World War. Through his own lobbying and some sympathetic naval physicians, he reentered the Navy, going to flight school in Pensacola, Florida, and earning his wings. He narrowly missed a chance to be among the first to fly across the north Atlantic in 1919, and did fly across it in 1927 (after Charles Lindbergh), though he was forced to land in the surf of Normandy, off Ver-sur-Mer, France.

By that time, Byrd had accomplished one of the stellar feats of interwar aviation: making the first flight to the North Pole, with pilot Floyd Bennett. Rose does it full credit, covering the difficult preparations and daunting circumstances. The flight, which started in Spitsbergen, Norway, on May 9, 1926, launched one of the greatest of aviation controversies: Did Bennett and Byrd actually reach the pole? If not, was their claim of success an honest mistake or a lie? Various claims and bitter partisanship have formed around individuals central to the story, including Byrd, Bennett, and Arctic explorer and aviator Bernt

TO ORDER THESE BOOKS FROM SMITHSONIAN SHOPS, CALL (202) 357-1387 OR -1388.

To some, sunglasses are a fashion accessory…

But When Driving, These Sunglasses May Save Your Life!

Drivers Alert: ***Driving can expose you to more dangerous glare than any sunny summer day at the beach can…do you know how to protect yourself?***

An amazing breakthrough in optic technology by NASA resulting in Eagle Eyes® can be your answer. The sun rises and sets at peak travel periods, during the early morning and afternoon rush hours. Many drivers find themselves temporarily blinded as they are driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare. Danger can come from reflected light off of another vehicle, from the pavement, or any other reflective surface. Early morning frost or dew can exacerbate this situation. Salted or snowy road conditions can make matters even worse. Yet, motorists struggle on despite being blinded by the sun's glare and cause countless accidents every year.

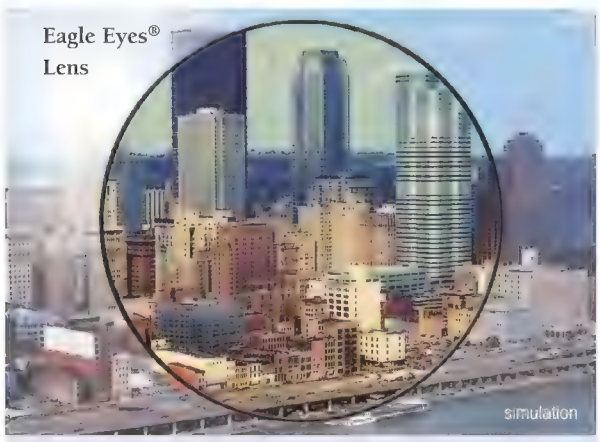
> *"As a board certified ophthalmologist, I recommend Eagle Eyes® to all my patients to protect and enhance their vision!"*
>
> 
>
> *—Dr. Lyda D. Tymiak*

Beware of windshield glare!

This glare-induced "blindness" is especially prevalent in the early morning or late in the afternoon, and due to the extremely reflective qualities of other cars. Even your windshield can make matters worse since wax and oil buildup can increase reflected glare. This powerful glare of the sun is damaging to the various layers of the eye. Certain road conditions may raise the amount of harmful UV that you are exposed to by 85%.

NASA's researchers looked to nature for a solution.

Conventional sunglasses can in fact blur your vision by exposing your eye to harmful UV, blue light rays, and reflective glare. They can also darken useful vision-enhancing light. At NASA's Jet Propulsion Laboratory, scientists looked to nature for a solution by studying the eyes of eagles, known for their extreme visual acuity. The result of this breakthrough optical technology is Eagle Eyes®. NASA's researchers studied how eagles can simultaneously distinguish their prey from their surroundings with utmost precision, while protecting their eyes from the daily exposure of harmful high-energy sunlight. These studies led to this revolutionary protection for human eyesight.



Slip on a pair of Eagle Eyes® and everything instantly appears more vivid and sharp. You'll immediately notice that your eyes are more comfortable and relaxed and you'll feel no need to squint. The scientifically designed sunglasses are not just fashion accessories—they are necessary to protect your eyes from those harmful rays produced by the sun during peak driving times.

Patented triple filtering lens system.

With a patented triple filtering system, Eagle Eyes® will reduce the blinding glare you may encounter while driving or enjoying outside activities. The lenses will block the UV light while enhancing the colors of your surrounding environment. Eagle Eyes® provides 100% eye protection from harmful blue, violet and ultraviolet light rays. You can experience enhanced visual acuity, even at great distances in most weather conditions. Even on cloudy days, the advanced lens technology improves your visual acuity.

Not just one pair–A second pair FREE!

Ninety-eight percent of people wearing Eagle Eyes love them. It's the highest customer satisfaction rate that we have seen in our 20 years history. We are so anxious for you to try the Eagle Eyes® breakthrough technology that when you call for the Eagle Eyes® Extremes™ we will give you the Explorers™ FREE!

That's two ways to protect your eyes and prevent blinding glare for less than the price of one pair of traditional sunglasses. You'll also receive free one hard leatherette case and one soft cloth pouch so you can carry and protect your Eagle Eyes® in style. Plus, if you are not thrilled with the Eagle Eyes® technology, just send them back for a full refund of the purchase price. You should always have a pair of sunglasses available when you drive, so put Eagle Eyes® in all of your cars and start seeing the world without the dangerous squinting and with more clarity than you've ever imagined.

Extremes™

Explorers™
FREE!
When you try the Eagle Eyes® Extremes™

POLARIZED • PATENTED Authentic SOLAR Lens Technology

Patented EAGLE EYES® uses NASA technology and are on display at NASA's Johnson Space Center.

Eagle Eyes® Sunglasses
Extremes™ ***only*** **$49.95** +S&H

Receive the Explorers™ absolutely FREE!—2 pair for the price of one!

Clip-ons available for $29.95 +S&H
Perfect for prescription glass wearers! We have four different clip-on sizes available. Please see our website ***www.nextten.com*** *for your correct size or ask your NextTen sales representative.*

Promotional Code EGL439-10
Please mention this when you call.
Call to order toll-free,
24 hours a day, 7 days a week.

800-859-1802

NEXTTEN
14101 Southcross Drive W.,
Dept. EGL439-10
Burnsville, Minnesota 55337

For information on all our products:
www.NextTen.com

Balchen. Rose carefully and fairly examines the relevancy and accuracy of each position and the supporting evidence. His conclusion: Byrd and Bennett did reach the pole, though alas, he is unlikely to convince committed conspiracy theorists.

Rose adds considerably to what we know of Byrd's Antarctic journeys, including his near-fatal attempt to spend the winter of 1934 alone on the Antarctic ice. It is a horrifying story of personal disintegration, fueled by poisoned air (from a defective stove), cold, and isolation: Byrd escaped death by only the narrowest of margins. Indeed, perhaps the strongest impression readers will carry away from this eminently readable book is just how lucky Byrd was: He survived at least four major aircraft accidents, several forced landings, long-term carbon monoxide poisoning, numerous crippling injuries, and getting lost at night and in a snowstorm on the Antarctic ice fields.

By 1941, Byrd was already in eclipse, and though the Navy continued to support his Antarctic endeavors, the challenges of the Second World War and then structuring the postwar world took precedence. Byrd made his last journey to Antarctica in 1956. After returning home, he died the next year.

Rose's book is superb, sympathetic but not sycophantic, grounded in primary sources and meticulously documented. It is so outstanding that readers will forgive the occasional error or simplification. For example: the Navy's Bureau of Aeronautics was not created in time for the First World War, but afterward. Billy Mitchell was far more nuanced than simply the "American apostle of strategic bombing" as Rose suggests. (Readers are advised to read Douglas Waller's *A Question of Loyalty: Gen. Billy Mitchell and the Court-Martial That Gripped the Nation* for Mitchell's fascinating story.) Byrd's last aircraft accident is said to have occurred in 1943 on page 420 and then 1944 on page 433; the former is correct. But the mistakes are minor and detract little from what is one of the finest aviation biographies ever written.

RICHARD P. HALLION, THE FORMER U.S. AIR FORCE HISTORIAN, IS THE 2007-2008 VERVILLE FELLOW AT THE NATIONAL AIR AND SPACE MUSEUM. HE IS THE AUTHOR OF NUMEROUS BOOKS, INCLUDING *TAKING FLIGHT: INVENTING THE AERIAL AGE FROM ANTIQUITY THROUGH THE FIRST WORLD WAR* (OXFORD UNIVERSITY PRESS, 2003).

>>> Gift Box <<<

Air Power Ties

Piston- and jet-powered aircraft make these ties the perfect Father's Day gift for airplane buffs. Made of 100-percent silk. $35. To order, call the National Air and Space Museum at (202) 357-1387.

>>> Fun Stuff <<<

COLLAGE ARTIST and Navion pilot David Peters spends a lot of time around airplane parts. As operations manager for an aircraft restoration business at Van Nuys Airport in southern California, Peters salvages scrapped parts, wraps them in aviation sectional charts, and turns them into whimsical teapot sculptures.

Fuel filters have convoluted surfaces and many ports, so they lend themselves to sculptures, says Peters. So do air-oil separators, which collect oil spraying from the action of the cylinders and return it to the engine. In a way, Peters performs the same function for discarded airplane parts. Instead of tossing them, he returns them to use. See the teapots at the del Mano Gallery Web site: *www.delmano.com/exhibitions/past/teapots.htm*.

LEFT: DAVID PETERS, COURTESY DEL MANO GALLERY; ABOVE: ERIC LONG

Turning the Odds in Your Favor

Probability Has Never Been More Interesting and Accessible Than in These 12 Lectures from The Teaching Company

Every time you buy stock or make plans based on a weather forecast, you are consigning your fate to probability.

What Are the Chances? Probability Made Clear helps you understand the random factors behind almost everything—from the combinations of genes that produced *you* to the high odds that the waiting time at a bus stop will be longer than the average time between buses.

Probability as a Reasoning Tool

Professor Michael Starbird knows the secret of making numbers come alive to nonmathematicians. He picks intriguing, useful, and entertaining examples, with questions such as: When did the most recent common ancestor of all humans live? How much should you pay for a stock option? What do you do on third down with long yardage?

After an introduction to the fundamental concepts of probability, you delve into a wealth of applications. Lectures 5 and 6 show that randomness and probability are central to physics and biology. Lecture 7 investigates the world of finance, particularly probabilistic models of stock and option behavior. Lecture 8 explores some unexpected applications of probability, and Lecture 9 examines two famous probability puzzles guaranteed to cause a stir: the birthday problem and the *Let's Make a Deal*® Monty Hall question.

Finally, Lectures 10 through 12 cover increasingly sophisticated and surprising results of probabilistic reasoning associated with Bayes theorem. The course concludes with probability paradoxes, including the notorious St. Petersburg paradox, involving a simple lottery in which the expected value is infinity; something has to be wrong, but can you guess what it is?

$$p \times 5 + (1 - p) \times 6 = p \times 7 + (1 - p) \times 1$$

$$(1 - p) \times 5 = p \times 2$$

$$5 = p \times 7$$

$$p = \frac{5}{7} = 0.714$$

Surprisingly, probability can be used to make a variety of decisions—one example is football. Here, p is the probability of the offensive team passing the football on 3rd and long yards.

About Your Professor

Professor Michael Starbird is a distinguished and highly popular teacher with an uncommon talent for making the wonders of mathematics clear. He is Professor of Mathematics and a Distinguished Teaching Professor at The University of Texas at Austin, where he has received the President's Associates Teaching Award, the Jean Holloway Award for Teaching Excellence, and the Friar Society Centennial Teaching Fellowship.

About The Teaching Company

We review hundreds of top-rated professors from America's best colleges and universities each year. From this extraordinary group we choose only those rated highest by panels of our customers. Fewer than 10% of these world-class scholar-teachers are selected to make The Great Courses®.

We've been doing this since 1990, producing more than 3,000 hours of material in modern and ancient history, philosophy, literature, fine arts, the sciences, and mathematics for intelligent, engaged, adult lifelong learners. If a course is ever less than completely satisfying, you may exchange it for another, or we will refund your money promptly.

Lecture Titles

1. Our Random World—Probability Defined
2. The Nature of Randomness
3. Expected Value—You Can Bet on It
4. Random Thoughts on Random Walks
5. Probability Phenomena of Physics
6. Probability Is in Our Genes
7. Options and Our Financial Future
8. Probability Where We Don't Expect It
9. Probability Surprises
10. Conundrums of Conditional Probability
11. Believe It or Not—Bayesian Probability
12. Probability Everywhere

THE TEACHING COMPANY®
The Joy of Lifelong Learning Every Day™
GREAT PROFESSORS, GREAT COURSES, GREAT VALUE GUARANTEED.™

About Our Sale Price Policy

Why is the sale price for this course so much lower than its standard price? Every course we make goes on sale at least once a year. Producing large quantities of only the sale courses keeps costs down and allows us to pass the savings on to you. This approach also enables us to fill your order immediately: 99% of all orders placed by 2:00 pm eastern time ship that same day. Order before August 5, 2008, to receive these savings.

SAVE $160!
OFFER GOOD UNTIL AUGUST 5, 2008

1-800-TEACH-12 (1-800-832-2412)
Fax: 703-378-3819

Special offer is available online at
www.TEACH12.com/3sas

The Great Courses®
THE TEACHING COMPANY
4151 Lafayette Center Drive, Suite 100
Chantilly, VA 20151-1232

Priority Code 27945

Please send me **What Are the Chances? Probability Made Clear**, which consists of twelve 30-minute lectures plus a Course Guidebook.

☐ **DVD $39.95** (std. price $199.95) **SAVE $160!**
plus $5 shipping, processing, and lifetime satisfaction guarantee.
Special price for shipping, processing, and lifetime satisfaction guarantee—this offer only.

☐ **Check or Money Order Enclosed**

* Non-U.S. Orders: Additional shipping charges apply. For more details, call us or visit the FAQ page on our website.

** Virginia residents please add 5% sales tax.

Charge my credit card:

☐ VISA ☐ ☐ DISCOVER ☐

ACCOUNT NUMBER EXP. DATE

SIGNATURE

NAME (PLEASE PRINT)

MAILING ADDRESS

CITY/STATE/ZIP

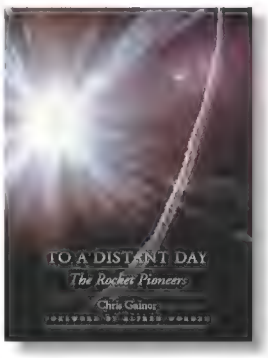
PHONE *(If we have questions regarding your order—required for international orders)*

☐ **FREE CATALOG.** Please send me a free copy of your current catalog no purchase necessary).

Special offer is available online at www.TEACH12.com/3sas
Offer Good Through: August 5, 2008

To a Distant Day: The Rocket Pioneers

by Chris Gainor. University of Nebraska Press, 2008. 264 pp., $29.95.



IN *TO A DISTANT DAY,* the author ambitiously attempts to summarize the history of spaceflight from the very first teachings of the ancient Greeks to the first manned spaceflight—Yuri Gagarin's flight on Vostok 1 on April 12, 1961. Gainor's first chapter is a wonderful, well-written summary of practically every spaceflight-related event occurring prior to the 20th century. His compelling opening paragraph explains that humans more closely resemble the composition of stars than that of Earth, perhaps explaining why we are innately driven to explore space.

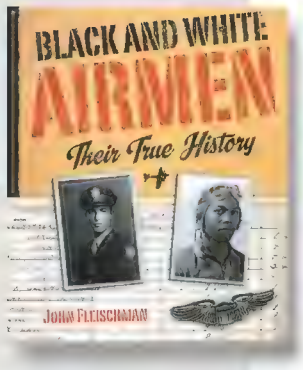
Condensing a few thousand years of history into only a handful of pages is difficult, however, and I quickly learned that this was a formula the writer used throughout the rest of the book—with mixed results.

Spaceflight is a product of the 20th century, when advances in rocketry were being made simultaneously in Europe, the United States, and the Soviet Union. A lot happened in that time, and Gainor does a remarkable job of capturing not only the events but also the inspiration that drove the efforts, such as books, films, and the burgeoning genre of science fiction. But in telling an enormously complicated story in slightly more than 200 pages, Gainor tries to include too much. Is it important to discuss Fritz von Opal's rocket car, which was little more than a stunt? The information in *To a Distant Day* is presented so rapidly that I sometimes felt I was flipping through baseball cards instead of the pages of a book. Though at times overwhelming, Gainor's book is nonetheless a thorough and accurate summary of early spaceflight.

BOB CRADDOCK IS A GEOLOGIST AT THE NATIONAL AIR AND SPACE MUSEUM.

>>> At a Glance <<<

Black and White Airmen: Their True History



by John Fleischman. Houghton Mifflin, 2007. 160 pp., $20.

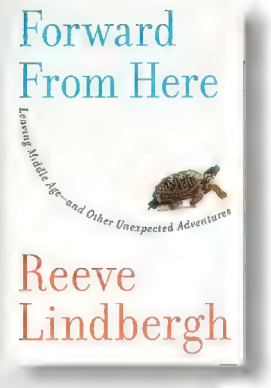
Frequent *Air & Space/Smithsonian* contributor John Fleischman has written a book for young readers about two World War II pilots – one black, one white – who flew in the segregated U.S. Army Air Forces. Years later, they meet and discover a common past.

Stargazing With Binoculars

by Robin Scagell and David Frydman. Firefly Books, 2008. 208 pp., $19.95.

Ideal for astronomy newcomers, this book guides readers on how to observe the night sky with just binoculars.

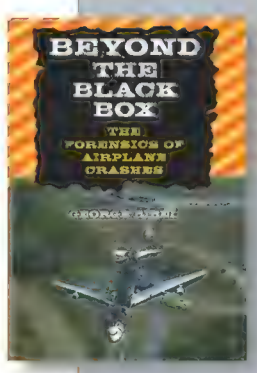
Forward From Here: Leaving Middle Age – and Other Unexpected Adventures



by Reeve Lindbergh. Simon & Schuster, 2008. 240 pp., $24.

In the last chapter of her latest memoir, a daughter of Charles and Ann Morrow Lindbergh talks about learning of her famous father's secret children in Europe and describes her trip to meet her extended family.

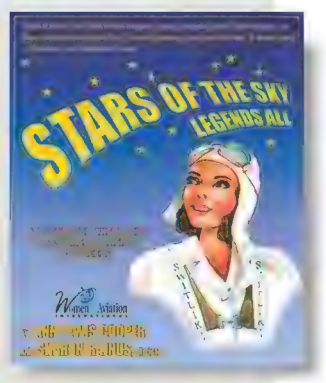
Beyond the Black Box: The Forensics of Airplane Crashes



by George Bibel. Johns Hopkins University Press, 2008. 393 pp., $30.

The author provides a thorough look at aviation accident investigations by analyzing such factors as fire patterns, metallurgy, and crash impact sites.

Stars of the Sky, Legends All: Illustrated Histories of Women Aviation Pioneers



by Ann L. Cooper and Sharon Rajnus. Zenith Press, 2008. 320 pp., $24.95.

Fifty female aviators, from airshow star Patty Wagstaff to space shuttle commander Eileen Collins, are profiled in this book, which features illustrations by aviation artist Sharon Rajnus.

[advertisement]

claroxan

PACIFICHEALTH

CALL 866.775.3937 OR VISIT WWW.CLAROXAN.COM TO LEARN MORE

Brian Grote is a flight instructor with years aviation experience. He also writes monthly columns on subjects pertaining to aviation.

FLYBY

ARTICLE WRITTEN BY: BRIAN GROTE

Dear Brian,

I've been flying for over 20 years. My usual run is a Denver departure at 9pm, fly to Billings, on to Cheyenne and then back to Denver by 5am. I fly a King Air 350. I love my career and I pride myself on doing the best job I possibly can.

Last time out, however, I was making lots of little mistakes. I was cleared for the ILS Runway 35R into Denver, but I couldn't pick up ATIS. That's when I looked at my radios and noticed I had dialed in the wrong frequency. I glanced again and dialed in the right frequency. I continued through my checklist and set my Radar Altimeter to 5500 feet. I was ready to make my descent and start my approach. After the outer marker I glanced at my DH again and noticed that I had set my Radar Altimeter, 67 feet low. Luckily, I landed safely, bouncing the wheels just a little.

After a couple more days in the sky I could tell my eyesight was beginning to deteriorate. I knew I wouldn't be able to renew my first class medical if I didn't do anything about it. I was really worried and started asking my peers if there was anything I could do. A co-worker gave me a bottle of Claroxan™ and told me it would help me maintain my depth perception. I was skeptical at first, but tried it anyway. As it turns out, the stuff works great. The problem is, I ran out and don't know where to find more. Have you heard of this Claroxan™ stuff? Is it available in the States?

Jason, 46 – Seattle, WA

Jason,

Not only do I know of Claroxan™, it just so happens I take it everyday. Being a pilot myself, I know that perfect visual acuity is an asset none of us can afford to lose. That's why every pilot should be protecting their eyesight before it's too late.

Claroxan™ contains ingredients proven beneficial for the eyes. Among these ingredients are lutein and zeaxanthin – powerful antioxidants that have been clinically proven to protect the retina and macula and, in some cases, reverse the damaging effects of macular degeneration. These antioxidants block damaging UV rays and halt damaging free radical oxidation in the back of the eyes. They have also been clinically proven to decrease the risk of cataracts.

Claroxan™ also contains bilberry, an antioxidant known to improve night vision. Bilberry's night vision enhancing effects were first noticed in England in the early 1940's. The RAF ordered English fighter pilots to eat bilberry jam on toast figuring it would give them an advantage during night raid missions against the German Luftwaffe fighters.

Claroxan's unique proprietary formulation is completely safe, all-natural and extremely affordable. As far as ordering it, you can call them toll-free at 866.775.3937, or go to www.claroxan.com. I usually get mine within a week after ordering.

Hope this helps!
Brian

THE Himalayan CATARACT project

The Himalayan Cataract Project strives to eradicate preventable and curable blindness in the Himalayas through high-quality ophthalmic care, education, and establishment of a sustainable eye care infrastructure.

Based in Asia, at Kathmandu in Nepal, the Project is empowering local physicians to alleviate the suffering caused by blindness through unique programs including skills-transfer education, cost-recovery, research, and the creation of a world-class network of eye care facilities.

In years past, PacificHealth donated a portion of profits to HCP for development and construction of eye facilities in the Himalayas.

Visit CureBlindness.org to learn more about HCP.

CLAROXAN™ | LEADER IN VISION IMPROVEMENT

Sunlight, aging, and diet each cause damage to the retina and macula, which can lead to a decline in vision that glasses or contacts can't help. If you've experienced an increase in blurriness or have difficulty seeing details at any range, then you know how valuable sharp vision can be. What you might not know is that in the past three years, a flood of new scientific research has been done on natural vision enhancement. This medical research suggests that ingredients in Claroxan™ may help maintain and even improve your vision, while at the same time giving you added protection against many ocular diseases

Claroxan™ may improve macular pigment density, which research shows has amazing effects on vision. By improving macular pigment density, ingredients in Claroxan™ may improve normal visual acuity, contrast sensitivity, and even glare reduction. Participants in one clinical study reported that ingredients in Claroxan™ improved their long range vision outdoors – in some cases, they were able to distinguish far away ridges up to 27 miles further than normal! Even if you have perfect vision now, Claroxan™ may help give you an edge by improving your visual reflexes and may allow you to pick up on moving objects faster than ever before.

People who count on their vision – people like pilots, hunters, military, and even pro athletes – trust Claroxan™ as the best source available for vision enhancement and protection. Claroxan™ is safe, effective, and extremely affordable. However, people with serious health concerns should consult a doctor before use.

AIR FORCE ONE FLIGHT BAG

NOT A REPLICA - THIS IS THE REAL THING!

These flight bags are given to staff and guests aboard **Air Force One.**

ORDER TODAY – VERY LIMITED SUPPLY.
www.whitehouseattic.com
TOLL FREE 866-952-8842 (866-95-ATTIC)
We also carry Air Force One & White House Luggage & Clothes.

ATHENA PHEROMONE 10x™

GET MORE AFFECTION FROM WOMEN WITH ATHENA'S 10X

Developed by Dr. Winnifred Cutler, 1986 co-discoverer of human pheromones. Unscented fragrance additives for men and women.

"Both my wife and I use your products and feel we are starting a new relationship with eachother."
-Gene, TX

"Married 35 years and thought it would be interesting to see if this will race my wife's engine a bit."
-Greg, CA

Call 610-827-2200 or view the science and Order Online at
Athenainstitute.com

www.motionmodels.com

THE WORLD'S FINEST QUALITY HANDCRAFTED READY-MADE MUSEUM QUALITY AIRCRAFT AND SHIP MODELS

The world's largest catalog selection & website of custon & ready-to-display aircraft & ship models. New 120-page catalog – $8.00 refundable – has over 1,000 models in color. Vets & active duty. . . let us custom make what you flew or served on. The perfect Christmas gift for a loved one.
REGISTERED DEPT. OF DEFENSE CONTRACTOR. MILITARY AND CORPORATE DISPLAYS

MOTION MODELS
2141 N. University Dr. #359, Coral Springs, FL 33071
1-800-866-3172

Air & Space/Smithsonian magazine is now available on audio tape for members who cannot read standard print due to disability. For the basic membership fee, you will receive a print copy of the magazine plus the audio version. If you or someone you know has been struggling with the standard print version because of vision loss or other disabilities, contact the Smithsonian Accessibility Program at 1-888-783-0001 and receive your next issue of *Air & Space* on tape.

Credits

The Bridge That Did Not Fall. Darrel Whitcomb writes about combat search and rescue. He is completing a book for the U.S. Army on medevac helicopter units.

The El Toro Follies. Michael Church has been teaching people to fly for 40 years.

Detect and Direct. Preston Lerner is a Los Angeles-based writer who was thrilled to get a ride in an E-2. His only gripe about the assignment was nearly drowning during the water survival training program that the U.S. Navy made him take first.

How Things Work: Thrust Vectoring. Jim Mathews wrote about pulse detonation engines ("Son of a Buzz Bomb") for the Aug./Sept. 2007 issue.

The Things It Carried. Thomas DeFrank, the Washington, D.C. bureau chief for the *New York Daily News*, is the author of *Write It When I'm Gone: Remarkable Off-the-Record Conversations with Gerald R. Ford* (G.P. Putnam's Sons, 2007).

Lockheed's Missing Link. Jorge and Karen Escalona are a freelance photographer/writer team.

The Few, the Brave, the Lucky. A writer and pilot in Cambridge, Massachusetts, Tom LeCompte flies an old but reliable Piper Cherokee.

Where the Sun Does Shine. Linda Shiner is the editor of *Air & Space/Smithsonian*.

Restoration: Arrow Sport. Ken Scott builds airplanes at his home in Oregon and flies them to his wife's concerts.

The Million-Mile Mission. Michael Klesius is an associate editor at *Air & Space*.

Towering Achievement. Kelly Nelson is an associate editor at *EAA Sport Aviation*.

Forecast

IN THE WINGS AND ON THE WEB

IN THE NEXT ISSUE

Destination Mars

Pay Dirt Can the once-proud Russian Space Agency stage a comeback with a risky soil-collecting trip to Phobos?

Expedition Six's Serendipitous Fall A rough landing in Kazakhstan may hold the key to a Mars mission.

ALSO...

LEGENDS OF VIETNAM: THE FIRST IN A SERIES

Daily Grind Conceived as a nuclear strike aircraft, the F-105 – and its pilots – gained fame on grueling bombing runs into North Vietnam.

A1C SHERYL D. BARNETT

Pilots loved the Thud's power, speed, and resilience.

Altered State Modern cockpits provide a wealth of information. Why, then, does pilot vertigo remain a problem?

COMING TO
www.airspacemag.com

Rare video of World War I "Jenny" trainers in flight, and test-flight footage of one of the hottest-looking fighters ever built: Lockheed's XF-90.

A noted historian gives his take on aircraft that changed aviation (see "Aircraft That Changed the World," p. 22).

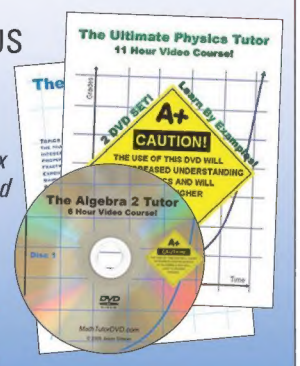
MATHTUTORDVD.COM
Press Play For Success

Having Math Problems?
WE CAN HELP!

SUBJECTS:
- BASIC MATH
- BASIC MATH WORD PROBLEMS
- PRE-ALGEBRA
- ALGEBRA 1 & 2
- ALGEBRA WORD PROBLEMS
- ADVANCED ALGEBRA
- GEOMETRY
- TRIG/PRECALCULUS
- CALCULUS 1, 2, 3
- PHYSICS

AVERAGE COURSE LENGTH: 8 HOURS
MOST COURSES COST ONLY $26.99

Subjects Coming Soon: Matrix Algebra, Unit Conversions, and Probability/Statistics.



VISIT OUR WEBSITE TO VIEW SAMPLE VIDEO CLIPS OF EVERY COURSE

#1 Rated Math & Physics Tutorial DVDs

All topics taught entirely through worked example problems.

Raise grades or your money back
877-MATH-DVD

Visit: MathTutorDVD.com/air

SPITFIRE
Warbird Shirts $22

888.977.5678
LOST SQUADRON®
WWW.LOSTSQUADRON.COM

Air Force, 14K Gold

When I set out to design a ring collection to recognize the history and culture of our great country, I knew it had to be beyond comparison. My rings had to be instantly recognizable, affordable to all and of the highest quality. They are just that.

Each ring is made one-at-a-time to your exact size and my exacting standards. They are heavy in weight, extreme in detail and made from the finest precious metals. Copyrighted & registered in the Library of Congress, made in the U.S. and 100% guaranteed by me. *Mike Carroll*

EagleRings.com
CARROLL COLLECTION OF US EAGLE RINGS
16144 W. Port Clinton Road, Prairie View, IL 60069
888-512-1333
Free Brochure
Twenty-Nine Original Designs

Visit the world's largest source of
commercial & military
aviation toys, models & collectibles

FREE COLOR CATALOG
Mention code AS01

The **AIRPLANE SHOP®**

Showrooms in
• New Jersey
• Las Vegas • Miami

Call 800-PLANE-GO
www.airplaneshop.com

24 Stewart Place, Unit 4, Fairfield, NJ 07004

A Farewell to Radar

THE JUDGES WHO AWARDED this year's Collier Trophy didn't choose an airplane or its designers; they selected something that is more of a concept than a piece of hardware. Actual operational equipment for Automatic Dependent Surveillance-Broadcast (ADS-B) has only a toehold so far on the world's air traffic management (ATM) systems. Still, the technology is so promising that almost everyone in the industry favors ADS-B to replace the radar-based systems that have served ATM so well since the Federal Aviation Agency was formed in 1958 to oversee air traffic safety.

In its day, radar was regarded as the near-miraculous technology that had helped the Allies win World War II. It displayed aircraft position night or day in all weather, enabling controllers to radio the information and instructions to pilots. But radar is expensive and hard to maintain. It can't reach past the horizon, and high terrain blocks it, creating blind spots for controllers. To scan the entire sky, its antennas have to be rotated by electric motors, and its electronics are complex. Radar was improved by the addition of aircraft-mounted transponders that transmit a four-digit identity code and altitude in hundreds of feet, enabling controllers to identify whose blip was whose and keep the traffic separated. Computers that processed the radar and data helped even more.

But the current system has two remaining drawbacks: Information has to be passed by voice and the information is in the wrong place—on a radar screen on the ground. When airspace is congested, voice communication is a clumsy way to move information. There are simply too many people talking at once. Every call by a controller or pilot has to be acknowledged to ensure it was heard. If two pilots key their mikes simultaneously, the calls are blocked, and at busy terminals this happens all the time, forcing callers to repeat themselves.

In ADS-B, satellite-borne transceivers use GPS and other navigation aids (such as an Inertial Reference Unit) to obtain aircraft position information, then transmit it to the electronic displays of everybody who needs it—not just air traffic controllers but other aircraft in the area as well (see "How Things Work: Aircraft Identification," Oct./Nov. 2006). And the system does this without requiring any voice communication, so in the future, the only times controllers will need to talk to a pilot by radio is when they see something abnormal. There are no blind spots, and the hardware involved (perhaps with the exception of the satellite systems) is simple and cheap and has no moving parts. And the transceivers, flying over the oceans and both poles, will be able to track aircraft in locations no radar could ever reach.

In the future, the only times air traffic controllers will need to talk to a pilot by radio is when they see something abnormal.

The NAA awarded the 2007 Collier Trophy to the teams that developed and implemented the Automatic Dependent Surveillance-Broadcast system.

MARK AVINO

ADS-B is already operating in China, Australia, and other areas with less extensive or entrenched radar-based systems, and is also being used by general aviation pilots in Alaska and air transport carriers in the Ohio River Valley; the FAA says that by the end of next year, the technology will be providing tracking information in the Gulf of Mexico, where dozens of helicopters fly workers to their oil rig platforms.

You can learn more about ADS-B at the Web site *www.adsb.gov*, which gives the schedule for the system's implementation in the United States and other details.

GEORGE C. LARSON, MEMBER, NAA